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By S. BARTER

AUTHOR OF 'MANUAL INSTRUCTION—WOODWORK'; ORGANISER AND INSTRUCTOR
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PREFACE

This little Work is intended to assist Teachers who are preparing for the Examinations of the City and Guilds of London Technical Institute.

As a text-book for general use, it will, it is hoped, be found useful to pupils of more advanced classes.

Manual Instruction has recently been added to the course of Organised Science Schools, and these also may find the following pages meet their requirements in some measure.

Solid Geometry might with advantage be taken concurrently with the examples given here. A common remark by students of Solid Geometry is that its application is not apparent, and it is this connection between the theory and its practical application that has been attempted in these pages.

S. BARTER.

March 19, 1896.

MANUAL INSTRUCTION—DRAWING

INTRODUCTION

It is intended to consider here the widely comprehensive subject, Drawing, from one point of view only, that of the manual training teacher—an aspect to some extent restricted, and yet of sufficient breadth to demand and deserve the most careful consideration.

Drawing of any kind is in itself a form of manual training. A child's hand must acquire dexterity, and his eye must be trained to accurate and intelligent observation, if he is set to draw.

The stimulation of the imagination and the strengthening and directing of the spirit of inquiry in the child mind are of themselves objects which every teacher regards, if not indeed as the goal of his labours, at least as the hardest portion of his work; and all will agree that, when once enthusiastic attention is secured in the pupils, the mere imparting of information is as much a pleasure to the teacher as to the class.

Drawing is, when properly taught, one of the subjects in which this can most readily be achieved; but not, however, by the series of spiritless, flat copies of conventional curves

combined into pictures of 'nondescript vegetables' which still find a measure of acceptance in our schools.

Drawing is essentially a living, interesting subject which is a mode of expression, in one or other of its forms, of any perceptions or emotions of whatsoever kind.

It lends itself with equal ease to the inspiration of the great artist, to the humour of the caricaturist, or to the most exact necessities of the map-maker or the engineer. It has at once the language of the vaguest suggestion and of the utmost precision.

A careful teacher, intelligent, knowing his subject, and unhampered by restrictions, has in his hands, by reason of its very adaptability, one of the strongest possible means of education.

Good teaching in any form of drawing, besides being a training in itself, is the best foundation for technical instruction; and, as most trades are more or less precise and definite in the nature of their requirements, mechanical drawing will usually be found to be the best form to suit the requirements of the technical teacher.

The report of the Pennsylvania State Commissioners in 1889 (p. 564) puts the case very well. It says, referring to mechanical drawing, 'For all material arts drawing is the language *par excellence* of a clearness, precision, and conciseness which the language of words cannot attain,' and, as language is the almost essential foundation of further mental education, so drawing is the natural starting point of nearly every form of technical education.

One of the most satisfying circumstances in connection with recent developments in education is that the teaching of

drawing is being affected by the awakened conviction that the 'whole boy' must be put to school, and that education must be really a training of the natural faculties, and not an unpalatable meal of indigestible facts.

The lads of the future, then, who pass into the care of the technical teacher will not be so unprepared as formerly to receive the more special training he can give them.

But, narrowing the question to the limits prescribed by the object of this treatise, let us consider the relationship of drawing to manual training, as we already have it in elementary schools.

By manual training we will now understand the more restricted branch of instruction covered by work in wood or iron, although only so limited from motives of expediency.

We will not consider at present the older established forms of the Kindergarten, nor the very interesting and valuable training afforded by clay modelling.

These forms of manual training are well established, and the methods and aims are admirable; but the newer manual training in wood and metal which is looked to with so much hope is likely to lose much of its effective value unless care be taken to guard against possible dangers.

One of the most important of these dangers is that drawing may be insufficiently or unwisely associated with the bench work.

I have endeavoured to show what I am conscious is not as deeply appreciated as could be wished, although to many of my readers it may appear unnecessary, that drawing in manual training is valuable in itself, and is the essential foundation of future development in the direction of technical education.

Although too many rules are undesirable, and in so elastic a subject as manual training dangerous to its healthy growth,

I will venture on the positive statement that a fully dimensioned paper drawing should be made of every piece of work before commencing, or concurrently with the bench work.

In the first place, the drawing practice must be good and useful.

Secondly, the child has the advantage of a clear notion of his piece of work as it is to appear when it leaves his hands, as well as precise instructions from his dimensions as to the size of all its parts. Any hazy ideas on the subject he may have are now removed.

Thirdly, he learns what a working drawing is; commencing with a very simple form, and gradually proceeding to the complex, until, when leaving the manual training room for ever, the making of working drawings has caused a lively appreciation for all that the technical teacher can show him of the more advanced forms.

The drawing of a technical workroom is directed towards the accomplishment of work solely. The instructor merely teaches the application of a knowledge of freehand, geometry, and projection, already gained by his pupils, elsewhere probably, but at any rate quite independently. In this connection it is found that, owing to the more difficult nature of the work to be done, the drawing becomes really indispensable, and unless his pupils have some previous knowledge of the making of working drawings, the difficulties of the technical instructor are much increased.

The drawing of a manual training room is, like the bench work, educational above all things. To teach the boy to draw, to acquaint him with the characteristics of the work which is to follow, based on his drawing, are the obvious objects in view, but there is more which is not quite so readily seen.

Not only must the drawing show what is to be made, but, as far as possible, it should indicate how to do it.

The methods in the technical room and in the manual training room are therefore different, although in both cases a complete working drawing of every piece of work is demanded and obtained.

With the workman, production is the main object. Every other consideration must stand aside. Speed in work, combined with good quality, is the one object of the skilled artisan.

In the economy of a trade workshop, drawing would probably be discarded altogether as a waste of time if it were possible to dispense with it; but, recognising the entire necessity of sufficient working drawings, the workman has devised methods which are intended to enable him to accomplish what he wants without wasting a moment in making an unnecessary line.

Unfortunately, many workmen of the older types have never been taught the scientific basis of this drawing, and, although they have learned by experience to understand the linear brevities of the architect's office in the case of familiar work, they are quite unable to read a new and peculiar drawing.

Division of labour has largely entered into many trades, partly in consequence of this defect of the men themselves, and partly because it is found more productive to set one good, intelligent workman to draw and 'set out' for many other merely executant workmen.

This division of labour has rendered the men still less acquainted with the theory of working drawing.

The younger men, however, who have the sound training of the Science and Art Department Classes to aid them, find the power of the theory with the startling rapidity of the workshop

method of immense advantage. Such men, however, do not yet form a very large proportion of those engaged in trades.

In the technical room this kind of drawing is now scientifically taught, but no subdivision of labour is allowed. Each pupil makes his own working drawing, so that he can, in due time, either draw or make anything within the scope of his trade.

In the manual training room the case is very different. The great object is to develop the child. The essence of the teaching is in 'the doing, not in the thing done.' Production is not aimed at; it merely follows as a consequence, and, although the drawing here happens to be the best foundation for the work of the technical teacher, this is not the main object of teaching it.

Mainly, it is to cultivate the natural faculties of observation and attention, and to train the hand to dexterity by the use of the drawing tools.

The drawing which will have to be done is necessarily largely mechanical; and to grasp thoroughly the principles of this drawing, plans, elevations, and sections must be clearly understood. But this is difficult with children, and, indeed, in some respects almost impossible.

To overcome the difficulty, the drawings made in the early stages should be, as early as possible, pictorial. This is also useful in the more advanced work, where the ordinary projections are not readily understood.

No division of labour leading to imitative work should be permitted. Each boy must make his own drawing, and, instead of making it in an abbreviated form, he must be taught to make as full, clear, and accurate a working drawing as is possible.

The drawings must not be copies, but should be constructed under the guidance of the teacher. Moreover, they should be made in a manner which will, while the drawings are being executed, bring home to the pupils a vivid impression of the exercises or models which are to be made from them.

It has been said that, in the early stages, or in difficult cases, the teaching will be much clearer for the introduction of as much as possible of pictorial effect.

No sketching in working drawings should be permitted. Accuracy is as desirable in this case as in any other, and should be as ever pre-eminent.

Freehand drawing should not, however, be banished from the workroom. It may be used in making drawings of tools and in completing curved lines of working drawings.

The combination of the accuracy of a working drawing with the vividness of a freehand sketch is a matter of some difficulty, but the solution of the problem is found in conventional drawing, of which the best form is isometric projection.

Isometric projection has several distinct advantages.

First, it is pictorial. A child can almost always see quite clearly what the bench problem is in the drawing when he cannot realise it from orthographic projections.

Secondly, it is easy, and for this reason alone it should be taken as early as possible.

The angles, being all either 30° or 120°, can be obtained from two similar set-squares. These set-squares should be used in the draughtsman's manner by arranging them against each other, so that the sum of two adjacent angles of the two set-squares may give the required angle, or by using one as a base to slide the other along, each square being used, possibly

alternately, as a T-square and a set-square. This plan is remarkably rapid and very safe.

One 60° set-square and a T-square can be used. This plan is not recommended for children in the early stages, as the T-square gives rather too much mechanical aid. It is preferable to induce the pupils early to a full use of the set-squares, as it fosters self-reliance.

Experience teaches that children have some difficulty in even holding the set-square firmly, which difficulty must be combated and overcome early in the instruction.

Thirdly, it is capable of logical demonstration. Elsewhere will be found an explanation of the theory of isometric projection; but we will pause to consider the objection sometimes raised, that children cannot understand the theory, and that it is better, therefore, not to attempt to teach anything which they will only learn mechanically.

In the first place, it is not true that none of the children can understand it, and for those who can it is an admitted advantage.

But for those who cannot – and it must be allowed that these are the majority—what are we to substitute?

Either inaccurate, unreliable freehand sketches, or conventional drawing. The latter has no scientific basis, and therefore no single child can possibly understand it in any other light than as a pictorial representation of the object, and that is exactly the light in which most children regard isometric projection.

The majority of the children, then, have the same difficulty with both isometric projection and conventional drawing, with this important difference, that isometric drawings can be made much more readily.

Isometric projection, it must be observed, can only be used for rectilinear drawings.

Beyond the elementary stage, the ordinary orthographic projections should be consistently used; and here, although the theory of plan and elevation can be told to children in simple cases, they will have some difficulty in even elementary sections. However, there is nothing insuperable in this, and much of the difficulty is caused by the insufficient knowledge of the theory underlying all working drawing. In other cases there is inability to apply the theoretical knowledge of geometry in practice, and it is the endeavour of the following pages to meet, as far as possible, the requirements of both these cases.

PROJECTION

The Drawing Tools.—We will not endeavour to prescribe what drawing instruments and appliances should be used in manual training and what should not be used.

Teachers, for whom this treatise is specially intended, requiring much wider practice must of course have many more instruments than those required for boys.

It is not proposed to describe the construction of any drawing instruments; but in the actual use of most of them certain methods which are indispensable, or really useful, are described.

Teachers should invariably be careful to prevent children from getting into the bad habit of drawing over an unsatisfactory line a second time in the hope of improving it.

The management of the set-squares is another matter known but not fully taught, and yet where this practice is understood, as by a draughtsman, the speed of work is remarkable.

The set-square is as much a tool as a hammer or a chisel, and dexterity with it is as much an object to a teacher.

With two common set-squares, a 60° and a 45°, and a plane scale such drawings as a square, rhombus, hexagon, octagon, and other plane figures can be made without the assistance of a T-square. This is done by moving the two set-squares about

each other. These two set-squares contain all the necessary angles for making a large number of plane figures.

This method of using set-squares is of use to any who are perfectly acquainted with the construction of the figures by geometry and who wish to save time in work. It would not, however, be applicable in the case of young children, who should be taught to construct the figures in the usual way.

Orthographic Projection.—Projection is a means of drawing any defined aspect of an object or any section of it.

The various dimensions of any object are not in any case easy of definite expression in a single picture, and in working drawings it is rarely attempted.

One picture is made to give the plan or its aspect as seen from a point of view exactly over it.

The elevation is the aspect of the front of the object carried to a plane surface behind it and at right angles to the given point of view.

If a rectangular slab of wood is placed in the right angle formed by the folding up of a sheet of paper along a straight line X Y, both the plan and the elevation can be drawn by marking with a pencil along the edges of the figure, at the line of contact with the paper, on the horizontal and vertical portions of the paper respectively.

The portion on the horizontal part of the paper is the plan, and that on the vertical portion of the paper is the elevation.

The plan gives two dimensions, the length and breadth, and the elevation gives the thickness of the slab.

A complete working drawing is now obtained with the plan and elevation separated by the fold in the paper.

Planes.—In actually making working drawings the paper is

not folded, but a line is drawn to indicate the intersection of the horizontal and vertical portions.

This line is called the X Y. Now planes are unlimited even surfaces in which any two points being taken, the line which joins them lies wholly in that plane, so that our vertical and horizontal sheets of paper are merely a device to represent portions of planes.

However, taking the model in fig. 1, it will at once be seen that the line of intersection X Y, is a hinge on which the vertical sheet can be folded in the direction of the arrows, until it merely doubles the thickness of the horizontal sheet, and in practice the whole of the single sheet of paper on which a drawing is made thus becomes as required either the horizontal or the vertical plane.

The horizontal and vertical or co-ordinate planes are, in drawing, represented by their trace or intersection, called X Y, as shown immediately above fig. 1.

But the co-ordinate are not the only planes. We may require one or several, either parallel to, or inclined at any angle to, either of the co-ordinate planes, on which to make new drawings of an object, and in any of these cases the new planes must intersect one or both co-ordinate planes.

Our sheet of paper can only indicate these planes by their lines of intersection or 'traces.'

Fig. 2 shows a new plane at right angles to the co-ordinate planes, tinted to distinguish it more clearly.

This plane makes a trace at its intersection with the vertical plane and another at its intersection with the horizontal plane. Both these traces are at right angles to X Y. When the co-ordinate planes are folded in the usual way the traces will be

shown as a straight line at right angles to X Y, as shown above fig. 2. A plane which is at right angles with the co-ordinate planes, is, then, always indicated in this way by its traces.

Fig. 3 shows a vertical plane, which is, however, inclined to the first vertical plane.

Being vertical, its vertical trace must be perpendicular to X Y, but being inclined to the vertical plane, its horizontal trace must be inclined to the X Y at the same angle as the new plane makes with the first vertical plane.

The two traces of this plane are shown above fig. 3.

Fig. 4 shows the converse of the preceding case. The new plane, being at right angles to the vertical plane, makes a horizontal trace at right angles to X Y, and, being inclined to the horizontal, makes a vertical trace inclined to X Y at the same angle as the plane itself is inclined to the horizontal plane.

The traces are again shown above the figure.

From these two cases it will be seen that if a plane is at right angles to either of the co-ordinate planes, one of its traces is at right angles to the plane to which it is perpendicular, and its opposite trace makes with the X Y the real angle of inclination of the plane.

The next case, fig. 5, is an oblique plane whose traces are both inclined to X Y, and neither of its traces makes the same angle with X Y that the plane makes with the co-ordinate planes.

Fig. 6 presents another new condition. Here the new plane is parallel to X Y, but inclined to the horizontal plane and vertical plane, and therefore its traces, as shown above, are parallel to X Y.

No matter what angle of inclination this plane makes to the vertical plane and horizontal plane, its traces will be parallel to

X Y, because the plane is parallel to X Y. This condition is the only one in which the horizontal and vertical traces will never intersect each other.

In all these planes the complement or sum of the angles of inclination of the new shaded planes cannot be less than 90°, as in fig. 6, nor greater than 180°, as in fig. 2, and as a consequence the supplement of the angles must make up at least 180° and at most 270°.

Thus in fig. 2 the supplement is 180°, and in fig. 6 it is 270°.

Points.—The drawings of points and lines on the planes are called 'projections.'

Projectors are drawn through the points to the vertical and horizontal planes, and give, in consequence, in one case the elevation, or the position in relation to the horizontal plane, and in the other the plan, or position in relation to the vertical plane.

Fig. 7. Draw X Y, and through it draw a line at right angle, extending as far below X Y as the actual point A is in front of the vertical plane, and as far above X Y as the point is above the horizontal plane.

The extremities of the line, marked *a a'*, are the plan and elevation of the point A. The sketch, fig. 8, shows the point projected on the co-ordinate planes, and the folding of the vertical plane into the horizontal plane is indicated by the arc in the second dihedral angle.

The result of this action is a continuous line from the plan to the elevation of the point, cutting X Y at right angles, or exactly what is shown in fig. 7.

From X Y set up a projector extending as far above X Y as the point B is behind the vertical plane. This gives the plan *b*.

Mark off on this line the height of the point above the horizontal plane, to give the elevation b'. Note that a point or line lying wholly in the second dihedral angle must have both its plan and elevation above X Y.

In the next case the point C lies below the horizontal plane and in front of the vertical plane. To find its plan and elevation, make a projector extending below X Y as far as the point is in front of the vertical plane. This gives the plan c. Over this projector lay another, extending from the X Y as far as the point is below the horizontal plane. This will give the elevation c'.

Note that a point situated in the fourth dihedral angle has both its plan and elevation below X Y.

The last case is that of a point, D, in the third dihedral angle. The plan in this case will be the extremity of a projector extending above X Y as far as the point is behind the vertical plane, and the elevation will be the extremity of a projector below the X Y, equal in length to the distance of the point below the horizontal plane.

Fig. 8 shows the projection of the four points in fig. 7 more clearly.

If a point is actually situated on the X Y, both its plan and elevation are on X Y.

Lines.—The projection of lines is very closely allied to the projection of points, but it presents one new feature.

Projections of a line may, under certain conditions, be less than the real length of the line.

If a line is parallel to the horizontal plane, its plan will show the real length of the line, but it may be inclined at various angles until it is vertical, and in each case the plan is shorter until at last it is a point. If, however, the line is in each case

parallel to the vertical plane, its elevation will continue to give the real length of the line.

If the line is inclined to both planes of projection, it will not be shown its real length in either plan or elevation.

Thus we see that lines are shown their real length in planes to which they are parallel.

Fig. 9 shows the plan and elevation of a line inclined to the horizontal plane and parallel to the vertical plane. We have given here the real length of the line, and on producing the elevation to X Y the angle of inclination to the horizontal plane, the height of the point A above the horizontal plane, and the distance of the line in front of the vertical plane are obtained. The sketch, fig. 10, is given to make the solution of this clear.

Figs. 11 and 12 show the converse of the preceding case; the real length of the line is shown in the plan, while the elevation is less than the real length.

Fig. 13 shows the plan and elevation of a line lying in both the first and second dihedral angles, and parallel to the horizontal plane. Its plan, of course, shows the real length, and intersects X Y at C.

Draw a line of indefinite length through X Y and at the desired angle to it. Mark on this line, from the point of intersection *c*, the length of the line which is known to be behind the vertical plane at *a*, and the length of the line known to be in front of the vertical plane at *b*. This gives the plan of the line—its real length.

Project *a b* into the X Y, and continue the projectors above X Y, equal to the height of the line above the horizontal plane.

Join the points *a′ b′* to obtain the elevation of the line A B.

The point c should be shown in elevation by raising a projector, *c c'*, to *a' b'*.

Fig. 14 makes this case clearer.

The next case (fig. 15) shows a line inclined to both planes of projection.

Draw the plan *a b* and the elevation *a' b'* of a line inclined to both planes of projection.

Now neither plan nor elevation gives the real length of the line, nor are the angles of either of its projections to X Y the real angle of inclination to either plane.

The line may be assumed to lie in a vertical plane whose H T (horizontal trace) is coincident with the plan. If this plane is revolved on its trace, $X^2 Y^2$, the real length of A B will be shown folded into the horizontal plane.

Make right projectors at right angles to *a b*, and mark off on them the heights above the horizontal plane, as in the elevation at *a b*. Join *a b*, and the real length of A B is given.

Produce *a b* until it intersects $X^2 Y^2$ at *c* to give the real angle θ of inclination of the line to the horizontal plane.

Similarly, the real length and the angle of inclination of the line to the vertical plane can be obtained from the elevation. Take a new inclined plane, whose trace $X^3 Y^3$ is inclined to the horizontal plane but perpendicular to the vertical plane, and containing A B. Revolve this plane on $X^3 Y^3$, and mark the distances of A B in front of the vertical plane at *a b*. Join *a b*, and the real length at A B is shown.

Produce *a b* until it intersects X Y at *d'*, and the angle of inclination ϕ of the line to the vertical plane is shown.

Fig. 16 is intended to render the problem clearer, and a cardboard model might well be made to show the two new planes.

Change of Ground Line.—In fig. 17 we have a simple case of change of ground line.

The plan of a block of wood and its front elevation are shown. The block is parallel to both planes of projection, and its height above the ground line and distance from the vertical plane are now ascertained, but its shape is not certain.

The plan and front elevation merely inform us that here we have an intersection of some surfaces on the block, but give no indication as to the real shape of the end. To complete the information given by the plan and front elevation as to the real shape of the block, it is necessary, then, to take a profile view of it.

A new plane at right angles to both co-ordinate planes is taken, and shown by its traces $X^2 Y^2$. In this case the vertical and horizontal traces are coincident.

The new plane is revolved on its vertical trace $X^2 Y^2$, as shown by the arcs *a b c*, into the vertical plane, and then turned into the horizontal plane on $X' Y'$.

Right projectors *a b c* are raised from the points of intersection of the arcs with $X' Y'$, and the elevation of the points of the drawing obtained by right projectors *f e d* from the front elevation.

The end elevation can be obtained by revolving the new plane on its horizontal trace as shown by the arcs *g h i* into the horizontal plane. From the arcs *g h i* make the projectors *g h i* below $X' Y'$, and the position of the points should be ascertained by right projectors *l l m m n n* from the plan.

The true shape of the block is now known, and we see that plan and elevation are not by any means always sufficient to work from.

This drawing has been made very amply to render it clear,

but in a workshop the artisan would merely have the section—in this case the end elevation—and the length given him.

The difference between the drawing of a manual training room and that of a workshop is in this instance well shown.

Fig. 18 is given to show the planes more clearly, and a card-board model should be made if there is any doubt as to the revolution of the planes.

Fig. 19 shows the plan, elevation, and end elevation of a prism, and is similar to fig. 17. Again, the real shape is only obtained by the end elevation.

Fig. 20 is the plan and end view of a cylinder.

The elevation of the cylinder is not shown, as it is exactly the same as the plan, and is not therefore necessary.

Fig. 21 shows plan and end view of an octagonal prism, and again the elevation, being similar to the plan, is dispensed with.

So far our instances have been easy, so that the revolution of the planes could be readily realised; but in later stages the planes are essential, and it is well to become accustomed early to their use.

Fig. 22 is another case of change of ground line. The wedge-shaped block is indicated by its plan and elevation, but to make a new plan showing the real shape of the inclined face a new plane, parallel to one of the faces, must be taken.

$X^2 Y^2$ is the trace of a plane parallel to $c' e'$, and by right projection through $X^2 Y^2$ from $c' d' e' f'$, and the measurements of width from the first plan, the new plan $a\ b\ g\ e\ c\ d\ h\ f$ is obtained, showing the real shape of the face $a\ c\ e\ g$.

Fig. 23. The plan shows the shape of a prism and the depth of two grooves on opposite sides of it. These grooves are shown in the elevation as a single pair of inclined lines, and

it is therefore clear that the two grooves are opposite to each other; but as one of the grooves on the inclined face is inclined to the other groove and is yet opposite to it, it cannot make the same angle with the edges on that side as the other groove with the edges on the front side.

If it were necessary to make this grooved prism, the bevel must be set at the proper angle in each case.

It is true that in this case the bevel need not be used at all, but instances might occur where the more scientific plan of finding the true angle for the bevel would be very useful, and perhaps indispensable.

The angle for the bevel in the case of the groove on the front side is seen in the elevation on $x' y'$ and marked with an arc, *a*. The front side being parallel to the vertical plane, its real shape is seen in the elevation.

To obtain a true elevation of the other face it will accordingly be necessary to take a new plane parallel to it and project the new elevation on this plane.

$x^2 y^2$ is the trace of the new plane, and on right projectors through $x^2 y^2$ a new elevation, with the true shape of the face, can be marked. The distance above the new ground line can be obtained from the original elevation.

The true angle of inclination of the groove to the edge is now seen, marked with an arc, *b*.

In fig. 24 we have another case of change of ground line.

The plan *a b c d* and elevation on $x' y'$ give full information as to the two slabs, but in neither is the true shape of the hole in the upright slab obtained. Here, as in the other two cases, a new elevation must be projected from the plan to a new plane, shown by its trace $x^2 y^2$, parallel to the face of the upright slab.

This case is again a very simple one, but the urgent necessity for a new plane to project the elevation of the upright slab would have been very clear had the details of the drawing been more elaborate.

In actually making this drawing the first elevation should not be completed, as regards the square hole, until the new elevation on $X^2 Y^2$ is completed. It can then be readily projected, as shown.

Sections.—Fig. 25 shows the working drawings of an oblong tray, made of two pieces of wood joined by a lapped dovetailed grooved joint.

In this case the elevation is given for one half of the tray, and the section on A B for the other half. The transverse section is shown on C D.

Fig. 26 is another tray made from a block of wood.

The plan shows the rounded ends of the groove, and the section on A B the semi-circular shape of the groove in a transverse direction.

The section on C D shows the shape of the ends of the grooves and of the outside of the tray at the ends.

In fig. 27 we have given the plan and section on A B of a moulding, and a new section inclined to the old one as shown at C D in the plan. It must be remembered that this line is really the trace of a new plane. From the points of intersection of C D with the plan draw right projectors.

On these projectors are marked the dimensions of thickness from the first section, and the new section on C D is completed.

Fig. 28 shows the working drawings of a portion of a piece of framing rebated on the back and chamfered on the front, with an angle bridle-joint at the corner.

The joint is mitred to the depth of the chamfer from the inner edge.

The angle of the chamfered portion of the framing and the dimensions of the rebate on the back are shown in the section on A B.

The section on C D shows one view of the joint, with the thickness and width of the tenon.

The section on E F shows that the two cheeks of the tenon are not of equal width, the back cheek being narrower owing to the rebating.

Fig. 29. The plan and elevation of a simple stopped, grooved, and tongued joint are given.

These drawings would be to a workman quite sufficient, but a beginner might have some difficulty in realising what is meant.

The groove is indicated by dotted lines in plan and elevation; but still a section through the middle of the joint as on A B is useful. This may be drawn anywhere through the plan of the tongue.

This section is shown for convenience in drawing, opposite to the elevation, instead of opposite to the plan, and note that it would have been possible to have dispensed altogether with the elevation if this section had been made at first. Then either plan and elevation or plan and section would have sufficed.

Fig 30 shows the plan and elevation of a hollow cube, butt mitred at all the joints.

The two drawings are quite similar, and one of them can be dispensed with, provided we understand that the drawing represents a cube.

For this reason one half of each drawing has been shown as a section.

Fig. 31. The working drawing of a simple bridle joint.

From the plan very little is learned as to the joint beyond the angle of inclination of one piece to the other, yet any one of several sections completes all the information it is necessary to have of this joint.

Three sections are given on A B, C D, and E F, all giving the same information.

Isometric Projection.—The theory of isometric projection can be best understood by drawing the projection of a cube standing on one corner, with one diagonal vertical to the plane of projection. Now, all the edges of the cube are of equal length and are equally inclined to the plane of projection. They are therefore projected of equal lengths in that plane, though the projection will not, of course, give the real length of the edges.

Draw three lines of equal length meeting in a point, and making 120° with each other. These make the projection of the front solid angle of the cube, and these lines are called the isometric axes, as from these all measurements are to be made.

Complete the cube, as shown in fig. 32, by drawing the opposite parallel edges to the isometric axes, using the set-square.

Notice the diagonals of the *faces* are shown in some cases foreshortened, as A F, A G, and A E, and in the other cases, being parallel to the plane of projection, as B C, C D, and D B, they are shown their real length. Thus, none of the diagonals of the faces being inclined to the plane of projection at the same angle as the edges, measurements which will apply to the latter, or to the lines parallel to them, will not serve for any other dimension. Hence the unsuitability of this form of drawing for any other than rectangular figures.

The real length of the edge is reduced in the projection in the following ratio; as $\sqrt[2]{3} : \sqrt[2]{2}$.

Therefore, to put the case inversely, the isometric is to the real length as the $\sqrt[2]{2}$ to $\sqrt[2]{3}$. The proof of this will be seen by a reference to fig. 33, and to Euclid, i. 47 and vi. 4.

Fig. 33 shows the section of the cube on A C E A′, and contains two sides, A C and A′ E, and two diagonals of faces, A E and A′ C. Now, the proportion of the edge of a cube to the diagonal of its face is as $\sqrt[2]{1} : \sqrt[2]{2}$ (Euclid, i. 47), and as A C = $\sqrt[2]{1}$ and A E = $\sqrt[2]{2}$, the diagonal of the cube A A′, being the side which subtends the right angle formed by them = $\sqrt[2]{3}$.

Draw C H, and project it into X Y at A′ K.

Now, the triangles A E A′ and A C A′ are equal, and, A C H and A A′ C being similar triangles, their sides are in common ratio.

Therefore, A C is to C H :: $\sqrt[2]{3} : \sqrt[2]{2}$; but C H = A′ K, which is the projected length of A C, and therefore the real length of the side is to the projected length as $\sqrt[2]{3}$ is to $\sqrt[2]{2}$. Based on these facts, Professor Farish devised a system of measurement to be applied to any solid rectilinear figure standing with its edges equally inclined to the plane of projection, with the object of making this form of drawing serve the purpose of plan, elevation, and section. Knowing the proportion of the real to the isometric length of any line, it is an easy matter to make an isometric scale.

Draw two lines A B and A C perpendicular to each other, and mark off on them equal parts at D and E as in fig. 34; join D E. Now D E = $\sqrt[2]{2}$ and A E $\sqrt[2]{1}$.

Mark off on A B, A F, equal in length to D E. Now, as A E = $\sqrt[2]{1}$ and A F = $\sqrt[2]{2}$, therefore E F, which should now be drawn, = $\sqrt[2]{3}$.

Real length measurements on E F, therefore, can be shown isometrically on A F by drawing lines parallel to E A from any given point in E F to A F.

Any of these lines will complete a triangle in common ratio to A E F.

And as A F is the isometric length of E F, so any distance in E F can be shown on A F similarly.

Draw on E F any plane scale, and in this way make an isometric scale of it.

In fig. 35 we have a simple case showing the rapidity of isometric drawing and its advantage as illustrative of the object without the necessity for plan or elevation.

A horizontal line A B should be drawn, and from the point C raise a perpendicular equal in length to the thickness of the block.

Make C D at 30° to A B equal in length to the width of the block, and C E at 30° to A B equal to the length of the block.

The figure can now be readily completed with the set-squares and **T**-square. The groove can be inserted afterwards.

Fig. 36 is another slab of wood, with a notch at one corner and a slot in the middle of the other end.

The block should first be drawn, as in the former case, and the notch and slot marked out afterwards on the top of the slab. The dotted lines to complete their shape can be projected from the top.

Fig. 37 is the isometric projection of a cube, with projecting slabs on the three visible faces.

Draw the isometric axes and complete the outline of the cube, afterwards adding the slabs as shown in the drawing.

Fig. 38 shows a double mortice and tenon joint, and fig. 39

is a slipped dovetail joint. In the case of fig. 38 the joint is drawn open, and in fig. 39 the joint is shown closed.

In making drawings of joints either of these methods is adopted as may be most expressive.

In these and all the preceding drawings on this plate the drawings have been pictorial representations, sufficient for the purpose, of objects which can be readily thought out by the draughtsman, but have to be drawn to convey an accurate impression to others, and are simple enough to be amply represented by their isometric projections.

Fig. 40 shows the plan of a Maltese cross.

In this case, not being so readily appreciated, the plan is useful and should be made first, drawing the figure and completing the square round it.

Now the isometric drawing (fig. 41) can be made very easily. Draw the outline of the square and add the thickness.

Mark the distance points made by the projectors on the plan and complete the cross. The isometric scale need not be used, and in reality the cross in the new position should have been smaller. Although technically accurate, this would have been almost useless as a working drawing, for it would have been necessary to convert all dimensions into the ordinary scale before they could have been used.

In many drawings it will be found impossible to make an isometric projection without first making one of the orthographic projections.

If it is desired to draw, say, a hollow prism of more than four sides, an end elevation or right section should be made.

In fig. 42 an end elevation of a hollow hexagonal prism is

shown. It is surrounded by a rectangle, and all necessary points are projected to the sides of the rectangle.

In fig. 43 we have the prism drawn isometrically.

The rectangle is first drawn (without using the isometric scale), and the hexagon is made within it from the elevation.

From this face the drawing of the prism can be completed as shown.

In fig. 44 the plan, end view, and section on A B of a shaped slab of wood is shown, and in fig. 45 the same slab appears, drawn isometrically.

The only difficulty here is the drawing of the semicircle. After obtaining the necessary points in the isometric projection as shown for the production of this curve, it should be sketched in as accurately as possible, or a French curve may be used.

Oblique Projection.—Oblique projection is a conventional form of drawing commonly used for freehand blackboard sketches and similar purposes.

The picture is projected by a series of parallel projectors oblique to the plane of projection.

The projectors may make any angle with the plane of projection.

Fig. 46 shows a block of wood projected in this way on a plane, P P P P.

The front face of the block is the same in P P P P as in the original.

Having drawn the face on P P P P from a' at any angle, draw a straight line to b'. This the projection of $a\,b$. Now all the lines parallel to $a\,b$ in the original will be drawn parallel to $a'\,b'$ in

the new drawing, and from this we learn that parallel lines are always drawn parallel in this form of projection.

In oblique projection it is usual, as in this case, to make one of the faces parallel to the plane of projection, and the essential feature of this form of projection is in the choice of the angle at which to make the other faces.

Fig. 47 shows a block, $a\,b\,c\,d$, say two inches thick, with a rectangular projection on one face.

A series of parallel projectors has been drawn $a\,a'$, $b\,b'$, $c\,c'$, $d\,d'$, and a new elevation made on these.

From d' in the projected elevation take $d'\,d''$ at any convenient angle with $d'\,c'$, and cut it off at such a length as will give a good impression of the thickness of the block.

The other edges parallel to $d'\,d''$ are now made, and the picture of the block completed.

It is rarely or never necessary to make projectors such as $a\,a'$, etc., in drawing a projection of this kind. If the form of the object is known, the drawing can be made on the elevation, as in fig. 48.

In fig. 47 and fig. 48 we have a technical peculiarity known to draughtsmen as shaded-line drawing.

Light is assumed to fall invariably on the object at an angle from the top left-hand corner of the drawing. The opposite sides of the object are, of course, in shade, and this shadow is indicated by thickening the lines on the right-hand side and at the bottom of a drawing.

From a knowledge of the principles of this shading alone, we can now see an important difference between fig. 47 and fig. 48. In fig. 48 the rectangular projection is replaced by a morticed hole of the same area.

Fig. 49 shows plan and elevation of a block of wood with a morticed hole in the middle and a slot cut on one end, with the two cheeks cut into a shoulder on one side.

These drawings are, strictly speaking, sufficient; but an elementary pupil might have some difficulty in realising what is meant, and to help him the sketch (fig. 50) has been made, partly projected from the plan and elevation.

Fig 51 shows two elevations of a double open mortice and tenon joint, and here again, to render them clearer, fig. 52 is given, showing an oblique projection of the joint.

Some of the construction lines are left in, and it should be noted that the figure here is best made by drawing the shape of the original blocks in faint lines and completing more firmly the outline of the figure within this outline.

Fig. 53 shows the plan and elevation of a dovetailed joint mitred on the edges.

Fig. 54 shows the two portions of the joint apart in oblique projection, and fig 55, in order to make the drawings yet more lucid, shows the piece A in fig. 54 reversed.

MISCELLANEOUS EXAMPLES.—Fig. 56 shows two elevations and a section on A B of a notched halving joint. Fig. 57 is an oblique projection of one of the portions of the joint, and fig. 58 an isometric projection of the joint, with one portion left dotted for the sake of clearness. This example is taken from the woodwork examination of the City and Guilds of London Technical Institutes' Examination for Teachers, in June 1893.

Fig. 59 is the elevation of one corner of a piece of framing with a stopped haunched mortice and tenon joint. The framing is shown to receive a panel.

Fig. 60 is a section through the rail and panel on A B, and

fig. 61 is an oblique projection of the joint open, and the corner of the panel ready to fit into the grooves in rail and stile.

Fig. 62 is the elevation of a double haunched mortice and tenon joint, and fig. 63 is the section through the joint on A B.

Fig. 64 is an oblique projection of the joint open.

Fig. 65 is the plan and elevation of an acute angle bridle joint and the end view of the piece B.

Fig. 66 is an oblique projection of the joint.

This is another instance from the papers set at the City and Guilds' Examination for Teachers (second year) in 1892.

Fig. 67 shows the working drawings of an oblique halving joint, and fig. 68 the oblique projection of the piece A.

Fig. 69 shows the working drawings of a piece of framing jointed at C C C C by a notched dovetail halving joint, and at D D by a bridle joint stopped on one face.

Fig. 70 is an oblique projection of joint D with the two parts separated.

Fig. 71 is an isometric projection of the same joint D reversed. In this case the joint is closed.

Fig. 72 is the oblique projection of the joint C in fig. 69, and fig. 73 is an isometric projection of the same joint.

Figs. 71 and 73 were given in order to afford a comparison between the oblique and the isometric projections in the case of these two joints.

Fig. 74 shows the working drawings of a piece of framing edge dovetailed and mitred at the corners. The framing is rebated on the back and stop chamfered on the front.

Fig. 75 is an enlarged detail of one corner showing the construction. This is usual in drawings of framings of this kind.

Fig. 76 is an isometric sketch added to make the drawing

clearer. All the working lines have been left, in this case, in order to show the method.

Fig. 77. In the key plan are shown three brackets supporting a shelf. The brackets *a a*, *a a*, are similar, and in the elevation on $X^1 Y^1$ the firm lines show the shape and portion of the construction of these brackets.

The plan on the top edge above the elevation and the side elevation complete the information as to the construction of these brackets.

The third bracket in the angle is required of similar construction and the same height, but the strut must have the corner of the lower edge, in the same plane as the lower edges of the struts in the other brackets.

Make $X^2 Y^2$ through *e* at the same angle to $X^1 Y^1$ as the plans of the brackets make with each other—in this case 45°.

Draw the projectors *b b*, *c c*, *d d*, *e e*, *f f*, from the elevation of bracket *a a* on $X^1 Y^1$ into $X^2 Y^2$, and on $X^2 Y^2$ draw the outline of the plan of the angle bracket.

With *e* as a centre and *e d*, *e c*, *e b*, and *e f* as successive radii, turn the points into the line $X^2 Y^2$.

Project the points from $X^2 Y^2$ into the lower edge of the top rail in the elevation on $X^1 Y^1$—viz. b' c' d', and f is projected into f'.

The dotted line in the elevation on $X^1 Y^1$ shows the new bracket with the construction, and the plan of the top edge is similarly completed.

Observe that the side elevation is common to all three brackets.

There is another way of obtaining the elevation of the angle bracket, as shown directly projected from $X^2 Y^2$ with the heights marked off as in the elevation on $X^1 Y^1$.

The plan on $x^2 y^2$ can now be completed as shown, and it will be found to exactly coincide with the plan above the elevation on $x^1 y^1$.

Fig. 78. Another similar bracket, with different forms of joints: oblique mortice and tenon, and at the corner marked B edge dovetail.

The plan, elevation, side elevation, and section on C D are given.

The angle bracket, as in the previous case, may be introduced here also, and it will be good practice to do it.

Fig. 79. The drawings of the framework of a footstool.

This has been taken as a somewhat advanced example of change of ground line.

The key-plan shows the general shape of the framework, and the remainder of the drawings show the details of one corner of the framework.

The enlarged plan is first drawn, and then $x^1 y^1$, parallel to the faces of the leg. Project an elevation to give the true shape of the leg. This may be of any design the pupil chooses.

The rail cannot yet be drawn, and a new elevation on $x^2 y^2$, parallel to the face of one of the rails, must now be inserted, showing the true shape of the rail.

We now have two elevations, and both of them incomplete: in one we have the leg and in the other the rail. We must now proceed to complete these elevations.

A series of horizontal planes should be cut through the leg on $x^1 y^1$, as shown at *a a a*, and at similar heights in the elevation on $x^2 y^2$ these planes should be shown again at *a a a*.

From the points where the curved line of the leg and the traces of these planes intersect drop projectors through $x^1 y^1$

into the plan, as the point b^1 is projected into $b\ b$. From the plan return these projectors, at right angles to $X^2\ Y^2$, into the other elevation, as $b\ b$ are projected into $b''\ b''$.

All the projectors are not completed, in order not to complicate the drawing.

Through the points where the various projectors intersect the corresponding plane in the elevation on $X^2\ Y^2$ draw a curve which will represent the new elevation of the leg.

To complete the elevation of the rail on $X^1\ Y^1$ drop a series of projectors, of which c is one, through the elevation on $X^2\ Y^2$ into the plan, and return these through $X^1\ Y^1$ into the other elevation.

We now must show the details of the construction.

The diagonal supports may be halved together, but that is too trivial a matter to be shown in these drawings. The ends of each piece are dovetailed into the legs to the depth of $d\ d$ in the elevation on $X^1\ Y^1$.

The horizontal section on A B shows this portion of the joint.

Below the dovetail is the joint of the rails with the leg. These rails are butted on to the leg, but to hold them more securely a tongue is inserted through a mortice in the leg and into each rail, as shown in the elevation on $X^1\ Y^1$ and in the section on C D.

In order to make matters rather clearer, a vertical section on E F has been taken, projected from $X^3\ Y^3$. This shows the true shape of the tongue.

Fig. 80. The plan of a block of wood is given at $a\ b\ c\ d$. It is required to cut a groove across this piece of wood at 60° with the long edges, one inch wide on the top face and half the depth of the wood. One side of the groove is to be upright, or at right angles to the face, and the other side to lie in a plane inclined at 60° to that face.

Draw the plan *a b c d*. Draw lines at 60° across the plan at the required distance apart. Draw the ground line A B at right angles to these across the plan. Let this represent a section plane. Draw A^2 B^2 parallel to it, and project the section of the block. The projectors *e f* carried into the top face at *e′ f′* on the section plane give the position of the groove.

Draw *f′ g′* at 60° to the face, to the depth of the groove, for the section of the sloping side.

Drop the projector *g* from g^1 into the plan. Draw the section plane D E. Project the section D E, making projections for the position of the groove from points in lines *e e*, *f f*, *g g*, and for the position of the groove on the edge make projectors from *f g* on the front edge of the block.

In cutting such a groove at a given angle it would have to be marked on the solid block. The angle to set the bevel for marking this groove on the edge of the block is therefore the angle marked with the arc K.

The next case is a very useful one. In fig. 81 we have the plan of two horizontal pieces of wood of different widths, all the similar surfaces of which are to make intersection in the vertical plane E F.

The dimensioned section of the narrow piece is shown on A B.

It is required to find the section of the other piece.

Draw C D at right angles to the edges of the wide piece and draw the section on it.

The height at back and front are as in the section on A B.

To hold a joint of this kind together, a groove is often cut from the inside, into which a tongue is inserted.

Draw the plan of the groove *a a a a* one inch wide and extending equally into each piece of wood.

In the section on E F mark the position of the groove in reference to height as shown.

Now it is clear that if this groove is deep there is a chance in making it of cutting through the wood and spoiling the appearance of the top surfaces. A projector $a\,a'\,a''$ should be made into the right section of the narrow piece of wood—i.e. the section on A B—and it can then be seen whether the thickness of wood at this point will admit of the groove being made of the given depth.

The height $a'\,a''$ determines that the top of the groove must be, say, $\frac{1}{8}''$ lower in order not to cut through the sloping surface.

Make another section on E F, and in this section mark the position and height of the groove.

A new section is given on the vertical plane G H, at right angles to E F, to render the drawing somewhat clearer, and to show the construction of the joint.

Raise perpendiculars from all the points of intersection on G H as shown, and draw the base of the section parallel to G H. Mark all the heights which can be obtained from the section on E F.

Note that the greatest height, $c'\,d'$, of the new section and the position of the groove are shown on $c\,d$ in the section on E F.

Fig. 82 is a similar case. One piece of wood $1\frac{1}{2}''$ wide is in section a quarter of a cylinder as shown, and is to be joined at right angles with another piece of wood $2\frac{1}{4}''$ wide on plan to give a joint, as in the case of fig. 81, with the two top curved surfaces meeting in a single line.

Draw the two pairs of lines representing the plan of the two pieces of wood, and E F, the trace of the plane of their intersection.

Draw the section of the narrow piece on A B, and draw a sufficient number of projectors from the curved surface in this section through A B to E F. From the intersection of these projectors with E F, raise other projectors at right angles to C D, and produced through C D indefinitely. On these projectors mark the same heights as in the section on A B: thus the height $e'f'$ will be marked on the new projector at $e''f''$. Join all these points in a curve, and we now have the shape of the section on C D.

To obtain the section on E F raise projectors from the points of intersection of the projectors already drawn with E F, and on these new projectors mark off the same heights as shown in section on A B; thus $e'f'$ is shown at $e'''f'''$. Join all these points, and we have the line of intersection.

Observe that if any of these three sections is given the other two can be found from it.

Fig. 83. An octagonal prism is to have a square piece mortised into it at any angle—in this case at 135.°

The difficulty here is the shape of the shoulders of the tenon. They have to be what mechanics call 'scribed' over the octagonal sides of the mortised piece—i.e. the octagonal prism.

If the two pieces were to be mutually perpendicular, the shape of the shoulders would be seen from the end view; but, as the square prism is sloping into the octagonal one, the shape of the shoulders and the length of the tenon will not appear on the edge, as in the end elevation.

In order to get the true view, we must take a section on A B.

Right projectors from the points of intersection of A B with the angles of the octagonal prism can be raised, and with the dimensions of thickness from the end view the section of the octagonal prism can be completed.

We now have the true shape to set out on the edge of the square prism, and the arcs *a a*, *a a*, show the angle at which to set the bevel on the base edge in order to set out the 'scribed' shoulders, and the arc *b b* shows the angle of the bevel for the sides.

Fig. 84 is a similar case to the last, showing the plan of two pieces of wood, one rectangular and one bevelled, joined by a mortice and tenon joint. The tenon is in the rectangular piece, and the mortice is in the bevelled piece.

The same question of the angle for the scribed shoulder of the tenon arises.

A new section on E F is raised, and the section now reveals the position of the tenon, and the angle *a a* is the angle to set the bevel for the scribed shoulder on the edge of the square piece of framing.

The angle *b b* on the plan shows the angle of the bevel for the sides.

Fig. 85. A vertical square prism piercing a slab sloping at a given angle.

The plan shows the right section of the prism and its position in relation to the slab, as well as the width of the latter.

The elevation shows the angle of inclination of the slab to the horizontal plane, and its thickness.

We now require to find the shape of the hole in the slab and its true position.

Projectors should be raised at right angles to A B from all the points of intersection of the two pieces.

The plan of the slab should be made at a convenient distance parallel to A B.

In the new plan the hole will of course be no wider from *a* to *b* than in the first plan.

Therefore the new plan of the mortice can be readily drawn in. This gives the true shape of the hole to set out on the slab.

Fig. 86. A vertical square prism supporting a sloping slab by a tenon through a mortice in the slab.

The plan and the elevation show the position of the prism and the slab in relation to each other.

In the plan, the position of the slab B has been shown in dotted lines.

A new plan is shown on C D with the shape and position of the mortice and the faint lines $a\,b$, $b\,c$, $c\,d$, $d\,a$ show the intersection between the prism and the slab.

The real difficulty of the drawing is in finding the angle to set the bevel for the shoulders of the tenon.

We must then find the real angle between the vertical edge of the prism and one of the lines of intersection joining it.

Let us take the vertical edge $c'\,c''$ and the line shown on plan at $c\,b$ and in elevation at $c''\,b$, and find the angle between them.

Draw $b'\,c'''$ parallel to X Y through b'.

Draw $c\,f$ in the plan perpendicular to $c\,b$ and equal in length to $c''\,c'''$.

Join $f\,b$, and the triangle $c\,f\,b$ is the development of the triangle, $c'''\,b'\,c''$. Therefore the angle $c\,f\,b$ is the angle to set the bevel for the shoulders.

The line $b\,f$ is of course equal in length to either $a\,b$, $b\,c$, $c\,d$, or $d\,a$ in the plan on C D.

Fig. 87. A cylinder penetrating obliquely two slabs of wood butt jointed and tenoned together. The plan and elevation give all that is required except the hole in the slabs.

To obtain this, draw a new plan of the pieces C and B parallel to their faces, as shown.

The plan of the hole now, is an ellipse—the section of a cylinder in a plane inclined to the axis is an ellipse.

In the new plan, we have projected the major axis; the minor axis is in this case the diameter of the cylinder.

Fig. 88 shows an accurate and easy method of making an ellipse.

Draw the major and minor axes. Take a slip of cardboard and mark from one end of it *c a* equal to half the minor axis; make also from *c*, *c b* equal to half the major axis.

If the cardboard be moved so that the point *a* travels along the major axis and the point *b* along the minor axis, the point *c* will be found to describe the line of the ellipse.

Fig. 89. Three pieces of wood A, B and C, are jointed together by butt-mitred joints, but the pieces are to be in relation to each other as shown in plan and elevation—i.e. A and B are horizontal and C is inclined to each.

The right section of A is *e f g h*, and that of B is *a b c d*. It should be observed that A, B and C have the same thickness.

The mitred joints are in vertical planes, but we must find the proper angle to set the bevel in order to cut off the ends of our pieces of wood.

Draw X^2 Y^2, and on projectors from *g h*, *d a*, through X^2 Y^2, make a new plan of the top.

The thickness of C is of course unaltered, but A and B now appear the width of their bevelled faces. This is the development of the top face of each piece and the angles at which to cut them off—i.e. the angles indicated by the arcs marked *n n* for pieces A and B, and *i i* for piece C.

Another way to have obtained these angles is as follows:

Take *e* as a centre and *e f* as a radius, and fold it into X Y.

Complete the revolution of the surface as shown by the faint lines in plan.

If the development is taken at the other end, draw a line E F parallel to X Y, and, with E as a centre, fold down *d* and *a* and project them into the plan. Complete the development as shown by the faint lines.

It will be clear that the angle of the bevel for the marking on the broad faces of the piece C is shown by the arcs *m*, *m*.

If the end elevation be consulted, the angle for the broad faces of pieces A and B will be found to be equal to the angle marked by the arcs *i*, *i*, or a right angle.

It is assumed that the student wishes to make a hollow square pyramid mitred together.

We will take the slope of the side as 45°, but the drawings given involve the same principle in any case.

The first thing to know is the size of the triangles making up the sloping sides of the pyramid.

Fig. 90 shows half the plan of the pyramid. On X^1 Y^1 make an elevation showing the side sloping at 45°. Raise a projector a' c' from a c, and where it cuts the sloping side we have the height of the pyramid equal to c' a'.

Draw an elevation of the half pyramid on X^2 Y^2 parallel to the plan of the sloping edge b a. The height can be obtained from the elevation on X^1 Y^1.

Therefore the line c'' a'' is equal to a c' a', or the axis of the pyramid.

Now a'' b'' = the real length of the sloping edge, and a'' b'' c'' represents the true angle of inclination of the edge to the base.

With a'' as a centre and a'' b'' as a radius draw the arc b'' d'.

With the length of the edge of the base *b d* as a radius, and with *a''* as a centre, describe an arc to cut the arc *b'' d'* in *d'*. Join *b'' d'* and join *a'' d'*, and we have the development or true shape of the side of the pyramid.

Before the joints can be made it is necessary to know the angle of inclination of the sides to each other, and of the sides to the base.

In order to solve the problem, an enlarged detail of one corner of the pyramid (fig. 91) has been taken.

The outline of the plan is first drawn, and then on $X^1 Y^1$, the sectional elevation, on A B. The slope of the side is of course 45°, as given. The thickness of the sides and base is also now apparent. The dotted line *a a* shows the joint if it should be mitred, and the firm line *a b* shows the joint at the base, if it is a butt joint.

Remember that this is a section perpendicular to base and face and their line of intersection, so that the real shape of the joint at the base is shown.

Now draw a sectional elevation on A C.

Make $X^2 Y^2$, and with the height from the section on $X^1 Y^1$ complete the new sectional elevation. This gives the real length of the portion of the sloping edge taken *l'' c'*, and the angle of inclination of the edge to the base.

To find the angles of the sides to each other is the next step.

The angle between two planes is contained by a plane which is perpendicular to the line of intersection.

A plane, then, perpendicular to the sloping edge *l c*, *l'' c'*, must contain the true angle of inclination of the sides to each other.

Such a plane as this is frequently called a cutting plane.

The vertical trace of this new plane should be drawn anywhere in the sectional elevation at right angles to $l'' c'$.

Draw the horizontal trace of this plane, at right angles to the plan $l c$.

Revolve the cutting plane on its horizontal trace into $x^2 y^2$. Take d as a centre and $d f''$ as a radius, and fold it down into $d f'$ Project f' into f.

Now observe that the two edges of the base are really horizontal traces of the planes of the faces.

Join fg and fh, and we now have the true shape of the intersection produced by the cutting plane.

The folding down into the plan, was done in making the arc $f'' f'$. The thickness of the wood has been added, and the bisection of the angle gfh will give the angle of the mitred edge of each face.

The next case is similar to the preceding one.

Fig. 92 shows the plan of two pieces of wood, each sloping at 60° to the ground line, as shown in the section on A B, and making in plan 45° with each other.

The section on A B shows the width of the pieces of wood, the angles of the two edges with the face side, and the angle of inclination with the ground.

To find the real shape of the two pieces of wood, take b' as a centre and $b' a'$ as a radius, and describe an arc cutting $x^1 y^1$ in g.

From a draw a line $a d$ parallel to $x^1 y^1$, and project the point g into it at d.

Join $d b$, and the real shape or development of the face side is given. The width is equal to $b' g$, and the angle at which to mark the face side for the joint is made at $d b e$.

To find the real length of the line of intersection raise $c a''$

at right angles to $a\,b$ on the plan, equal in length to the height above the ground line as shown at $c'\,a'$ in the section on A B.

Join $a''\,b$ to give the real length of the line of intersection and the angle of inclination of this line with the horizontal plane. If b is taken as a centre and $b\,a''$ as a radius, the arc will be found to cut $b\,d$ at d, showing that the line of intersection of the faces and the length of the sloping edge of either of the pieces of wood are equal.

To find the angle the sides make with each other, we must introduce a cutting plane perpendicular to the line of intersection.

This is shown by its vertical trace at right angles to $b\,a''$, and where it cuts the plan of the line of intersection $b\,a$ make the horizontal trace of the new cutting plane at right angles to $b\,a$.

From the point h turn $h\,f$ down into $b\,a$ at f''. Join $f''\,i$ and $f''\,j$, and we have the development of the section on the new cutting plane.

Complete the section with the thickness of timber shown in the section on A B, and we now have the angle to set the bevel for the mitre.

Fig. 93. The plan and elevation of two pieces of wood tongued together, with another piece butt jointed to them, in the right angle between them.

The thickness of the new piece of wood has been purposely omitted in both plan and elevation, but we require to know its true shape, and the angle between the faces and edges, so that it can be cut off and fitted at once to the other two pieces of wood, at the required angle.

The bottom edge of the oblique piece is to be bevelled, so that it is horizontal when fitted into its place.

From a make $x^2 y^2$, cutting $b c$ at right angles. Let this represent the trace of a new vertical plane. From $x^2 y^2$ make $a d''$ equal to $a' d'$.

Join $e d''$, and the angle $a e d''$ is the angle to set the bevel for the bottom edge.

To obtain the development of the triangle take e as a centre and $e d''$ as a radius, and make an arc cutting $x^2 y^2$ in f.

Join $f c$, and $f b$, and the triangle $b f c$ is the development.

All that now remains is the angle to cut the edges of the other two sides.

They are equally inclined to their respective faces of the tongued joint, so that if we take one edge and determine the angle to set the bevel we know that the other one will be similar.

The elevation on $x^1 y^1$ shows the line of intersection of the top face of the oblique piece of wood, with one of the upright faces, and if we take a cutting plane perpendicular to this line, it must contain a right section of the bevelled edge.

Draw the vertical trace of this cutting plane at right angles to $b' d'$.

With i as a centre and $i\ h''$ as a radius, fold down the new plane into $x^1 y^1$.

Project h' into the plan at h. Join $h g$, and $h g a$ is the angle of inclination of the bevelled edge of the triangular slab.

Fig. 94. Plan and elevation of an oblique housing joint. In this case the angles of a tub or tray. The thickness of the bottom has been left out to avoid confusion.

Fig. 94 shows the plan and elevation on $x^1 y^1$ and another elevation on $x^2 y^2$.

Draw the sectional elevation on $x^1 y^1$, and we now have the true section of one of the sides.

Drop projectors from this elevation through $X^1 Y^1$ for the plan. Now draw the other sectional elevation on $X^2 Y^2$. Drop projectors from this elevation through $X^2 Y^2$ to cross the other projectors from the first elevation.

From the points of intersection of the projectors from $X^1 Y^1$ with the corresponding projectors from $X^2 Y^2$, portion of the outline of the plan can be completed. But the plan of the sloping corner will not be shown.

The lines $n j$ and $o l$ are parallel to $p k$, and where they cut the projectors from $j' l'$ in elevation on $X^2 Y^2$ we have the plan of the outer corners, from which the plan can be completed.

It is required to know the various angles to set the bevel and the development of the faces.

The first step toward this end is to find the angle of the oblique faces.

Fig. 95. A plan of the sloping faces without the thickness to show the real angle between the inner sloping faces.

On $X^3 Y^3$ raise a perpendicular $a a''$ equal in height to $a a'$ on $X^1 Y^1$.

Join $a'' b$, to give the real length and angle of inclination of the line of intersection of the faces.

Draw the vertical trace of a cutting plane at right angles to the line of intersection $a'' b$ cutting $a b$.

From g draw the horizontal trace of the cutting plane at right angles to $a b$ to cut the horizontal traces of the inclined faces in f and e.

With g as a centre and $g i$ as radius describe an arc $i i''$ into $X^3 Y^3$.

Join $i'' e$ and $i'' f$. We now have the true angle between the faces, and on it can be completed the section as shown.

To find the development of the faces, with p as a centre and $p\,k$ as radius, make the arc $k'\,m$, and draw the edge of the development now folded into the paper.

To complete this development, with n' as a centre and $n'\,j'$ as a radius draw the arc $j'\,r$. Draw $r\,j''$ parallel to $X^2\,Y^2$

Join $j''\;n'$, join $j''\,s$, join $s\;p'$, and join $t\;w$. This gives the development of the face, the position of the groove marked out on it, and the angle for the groove. This will also be the angle on the side to cut off the ends which go into the grooves.

Produce the projectors from the plan through $X^2\,Y^2$ till they are clear of the elevation and the dotted lines, $v\,v\,v\,v$, give the angle with the face side copied from the section, to set the bevel on the edge, for the groove and ends.

The development is easily distinguished by being in fainter lines than the remainder.

Fig. 96 is similar to the preceding, but the sides of the box are to be joined by oblique, dovetailed joints, and the top and bottom of the edges of the sides are to be horizontal.

Draw the outlines of the end elevations on $X^1\,Y^1$, omitting the pins. The angle of inclination is 120°.

Project the plan from the elevation, omitting the pins, which can here serve no purpose. As in the preceding case, introduce a cutting plane at right angles to the line of intersection to find the true section and angle of inclination of the faces to each other.

To find the development, take b as a centre, and with $b\,c''$ as a radius describe the arc cutting $X^1\,Y^1$ in c'.

Project c' into c, and draw a long projector from b parallel to $c'\,c$.

Now $b\,c'$ equals the true width of the faces.

We next want to know the angle to cut off the wood at each end of the face.

Make $e\,d$ equal to $a\,c''$. Join $e\,c$. This is the development of the inner face, and gives the angle to set the bevel for the end.

Make $f\,g$ equal to $a\,c''$. Join $g\,h$, fig. 98. This is the development of the adjacent side of the joint.

One of these pieces of wood has to be cut with pins and the other with sockets to receive them.

To obtain the end view of pieces A and B make $j\,i$ in each piece equal to $b\,n$, or the horizontal thickness of the piece on the edge. Make $e\,k$ and $g\,k$ also equal to $b\,n$.

In fig. 97 draw $j\,j$, $i\,i$, and $k\,k$ parallel to $c\,e$.

Similarly the end of piece B can be shown in fig. 98 by $j\,j$, $i\,i$, and $k\,k$ parallel to $g\,h$.

On the end of piece A mark the position of the pins and half pins, as shown.

Project all the points of these pins in this direction through the piece B and in the other direction into $X^1\,Y^1$. With b as a centre fold all these points back into $b\,c''$.

Through the points in $b\,c''$ draw projectors, where necessary, parallel to $X^1\,Y^1$ through both the elevations. The elevations can now be completed.

In piece B the plan has been completed by some faint dotted lines. It has been left out in piece A to avoid further complications in the drawing.

Make $h\,m$ and $k\,m$ in piece B equal to $c''\,m$, and from these the plan can be completed.

In this case the drawings have shown very fully all that is required to make the case clearer to the pupil. But in a workshop

a much simpler plan might be adopted; both the elevations and the development of the pieces, as we have shown them, are discarded.

The plan as we have it is used, and the section on the cutting plane is obtained, but now the workman proceeds rather differently.

We know that the height is equal to $o\,p$, since op was made equal to $b\,a$. This might have been given in figures, say 1 foot.

Produce two of the top edges to s and t, make $r\,s$ equal to the length of the line of intersection $r\,p$, and draw $u\,t$ parallel to $r\,s$. We now have the edge of the end of either piece, on which the ends of the pins can be drawn, and the figure $u\,r\,s\,w$ shows the development of the end of one of the faces.

PLATE 1

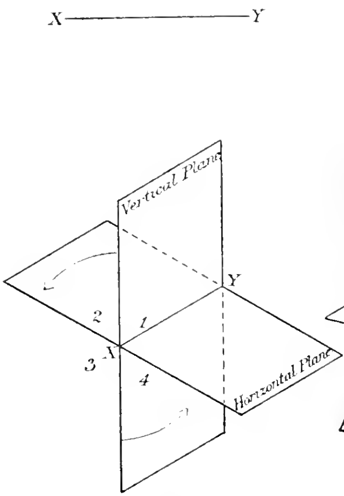


FIG. 1

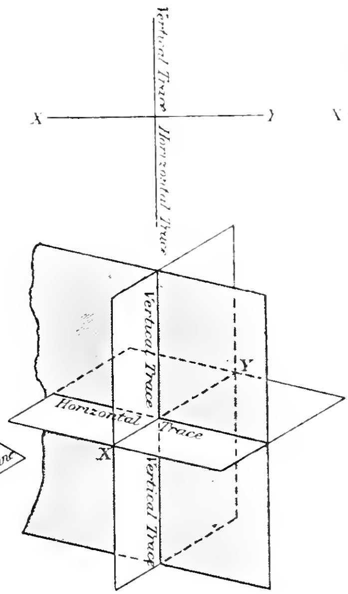


FIG 2

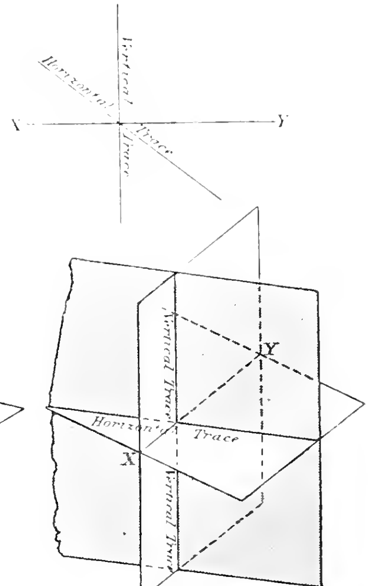


FIG. 3

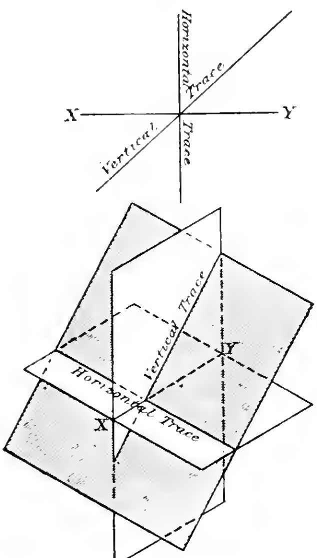


FIG. 4

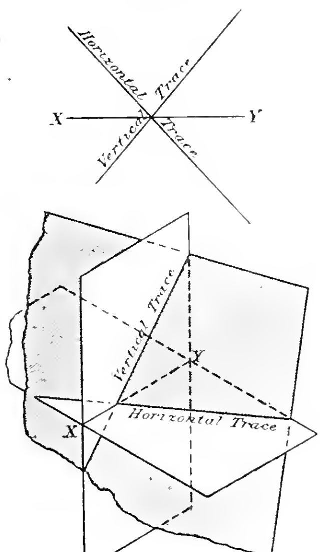


FIG. 5

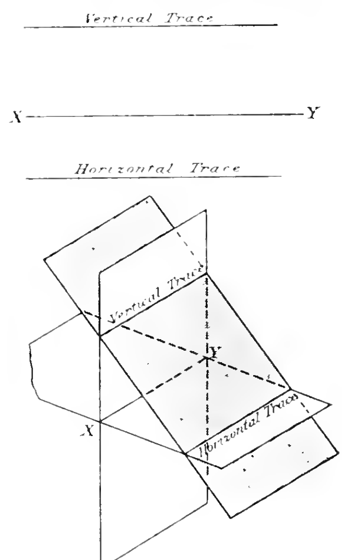


FIG. 6

PLATE 2

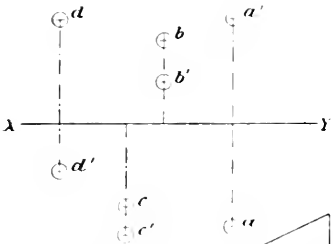


FIG 7

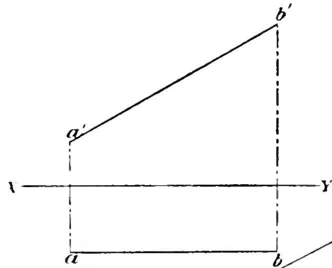


FIG 9

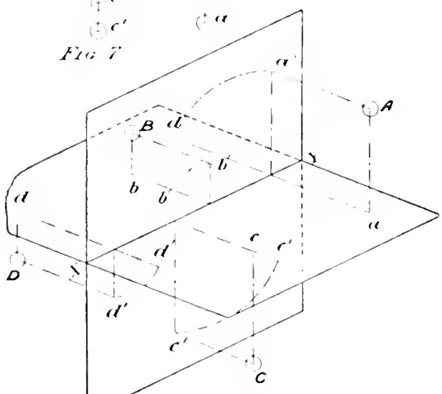


FIG 8

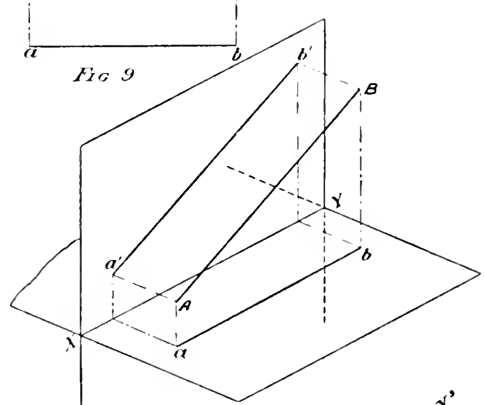


FIG 10

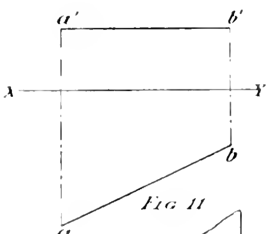


FIG 11

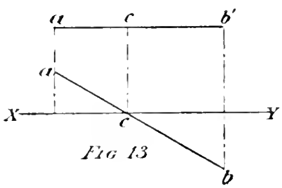


FIG 13

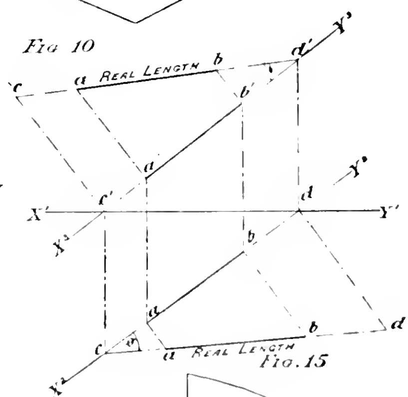


FIG. 15

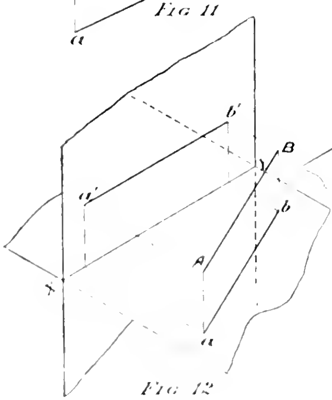


FIG 12

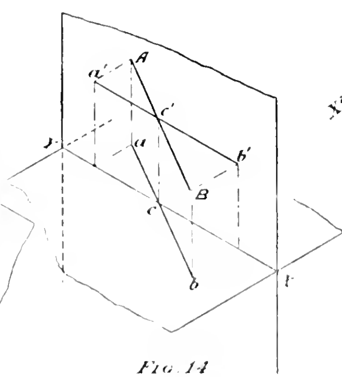


FIG. 14

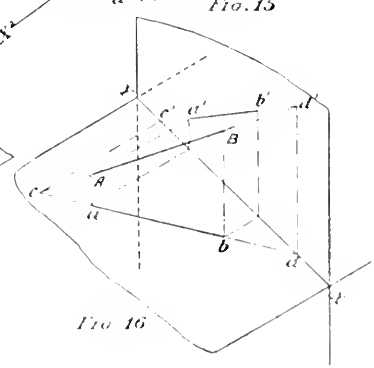


FIG 16

PLATE 3

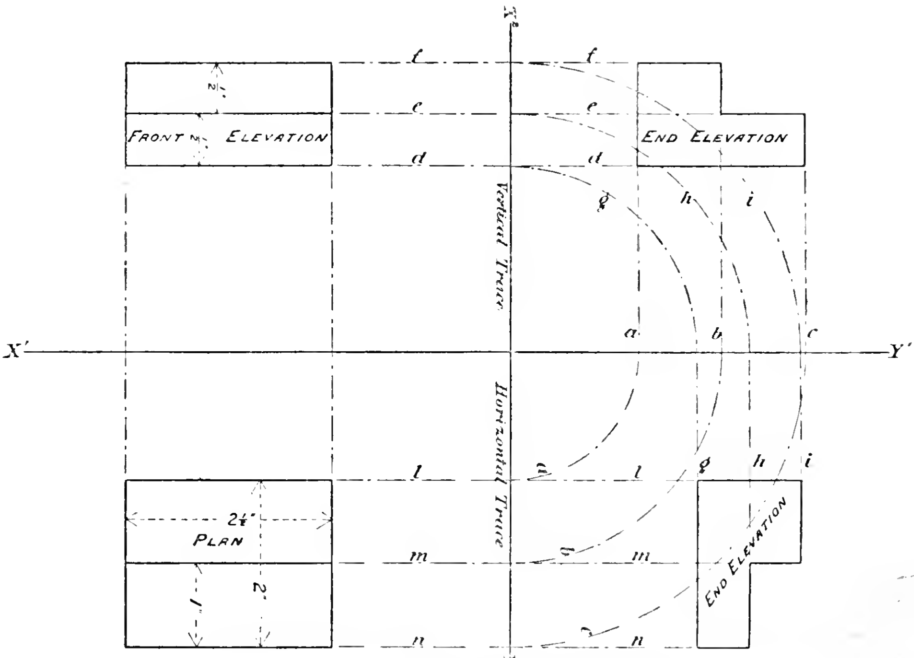


FIG 17

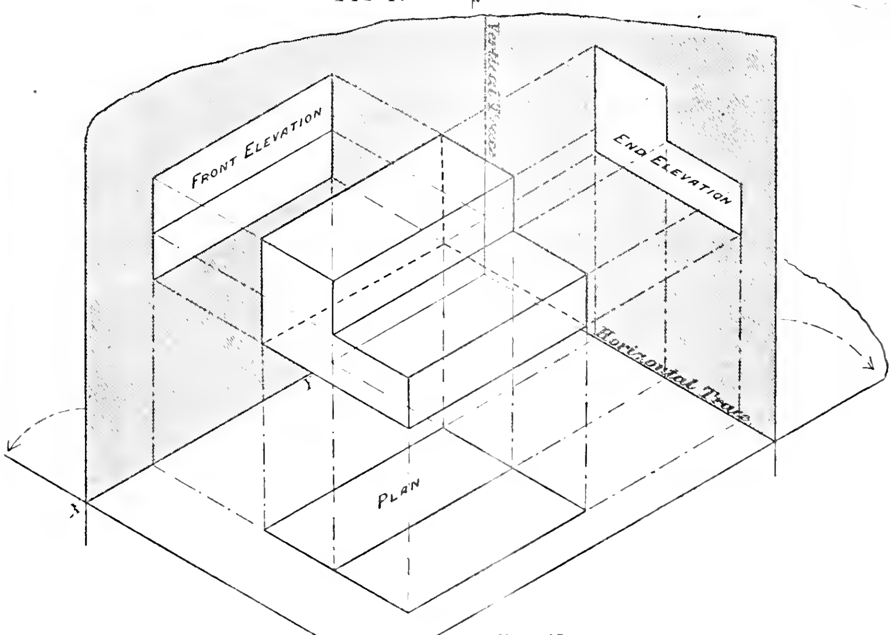


FIG. 18

PLATE 4

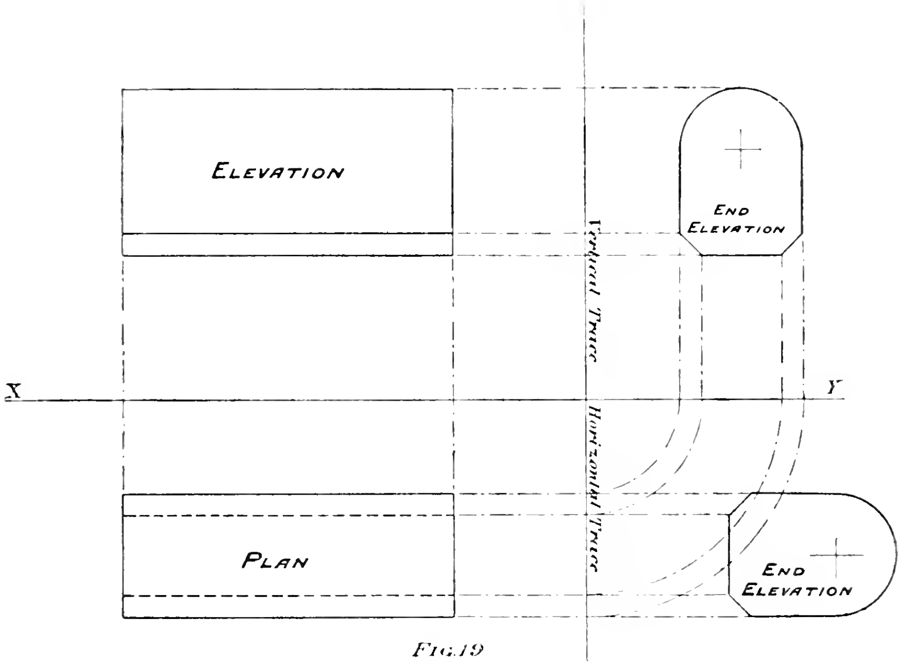


Fig. 19

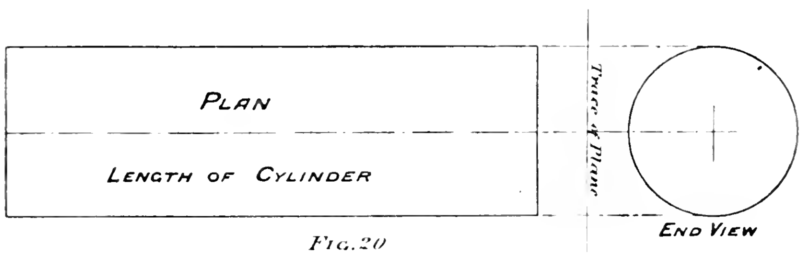


Fig. 20

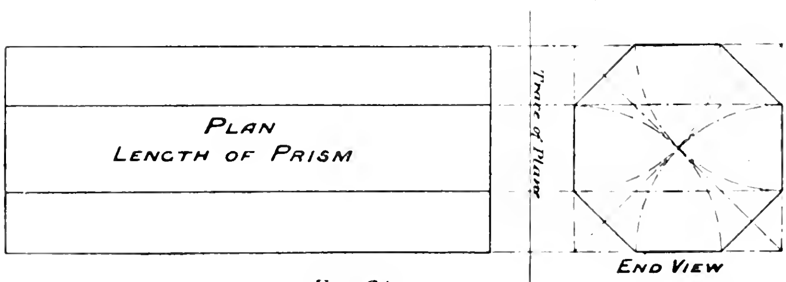


Fig. 21

PLATE 5

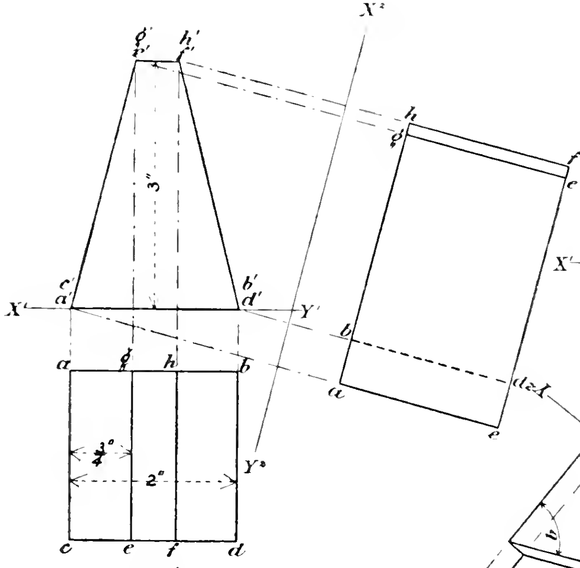


FIG. 22.

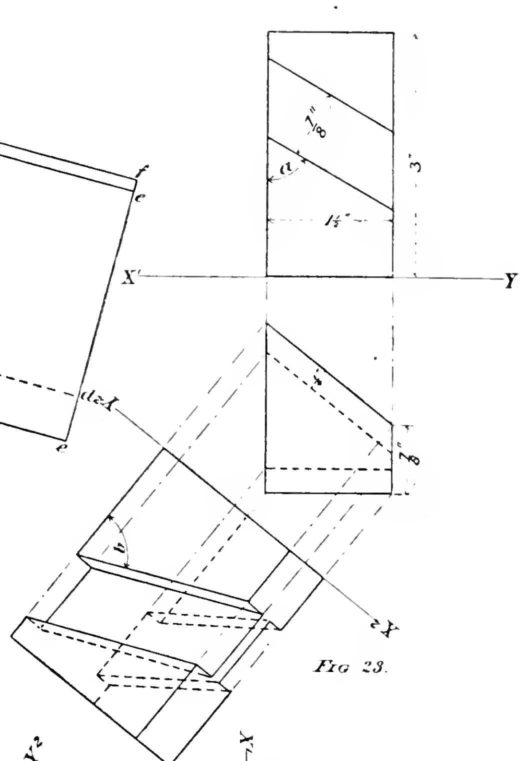
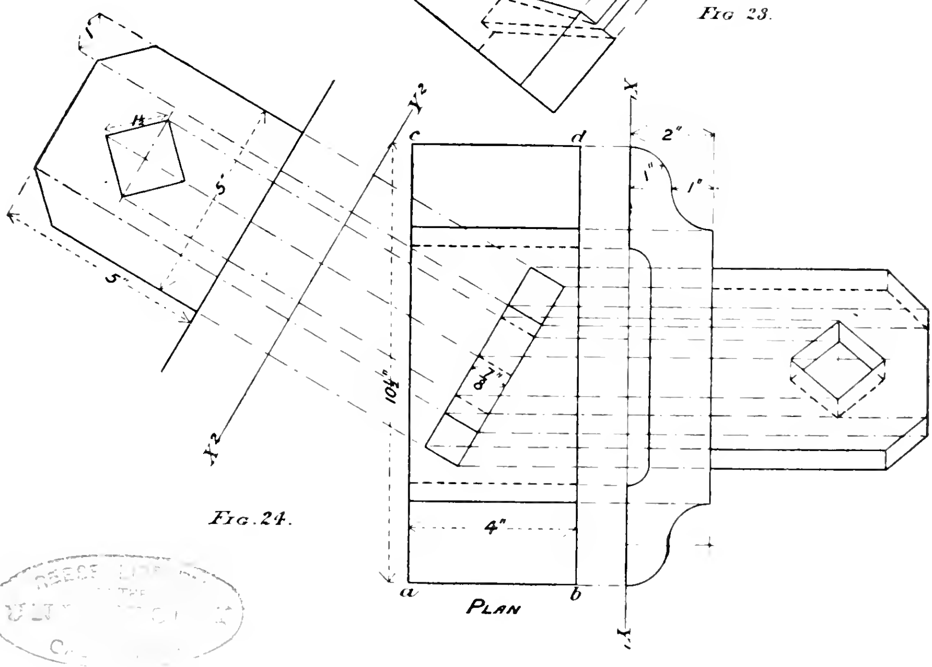


FIG 23.



PLAN

FIG. 24.

PLATE 6

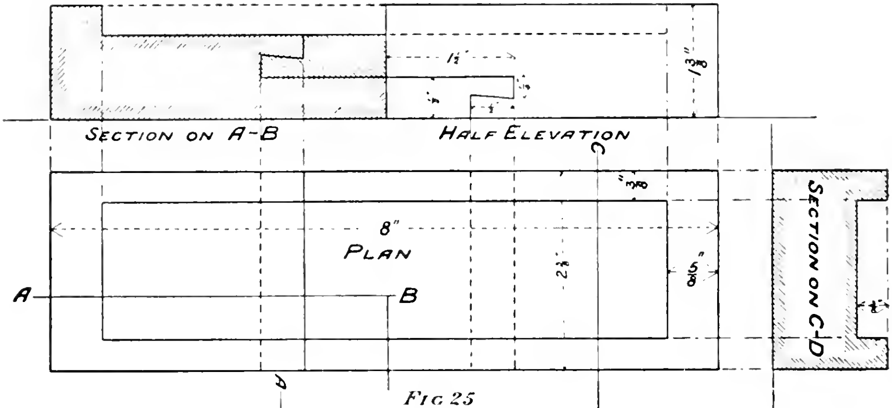


Fig 25

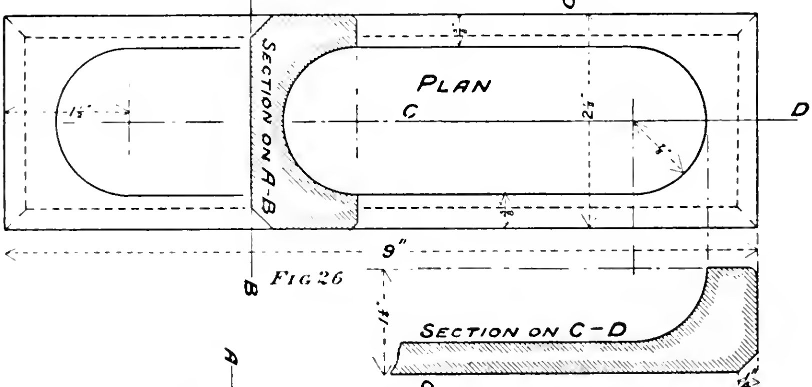


Fig 26

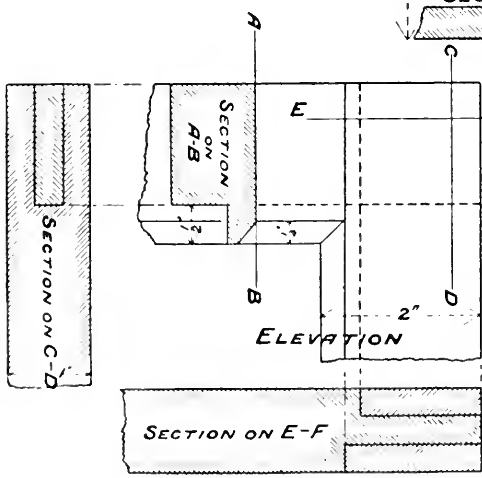


Fig 28

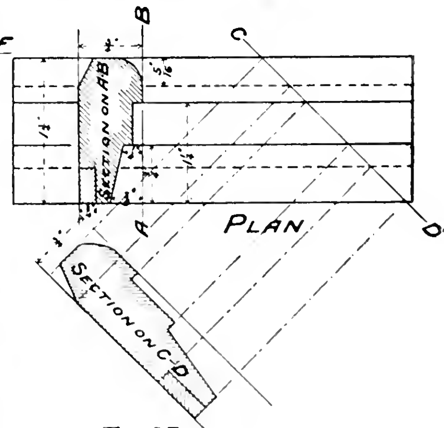


Fig 27

PLATE 7

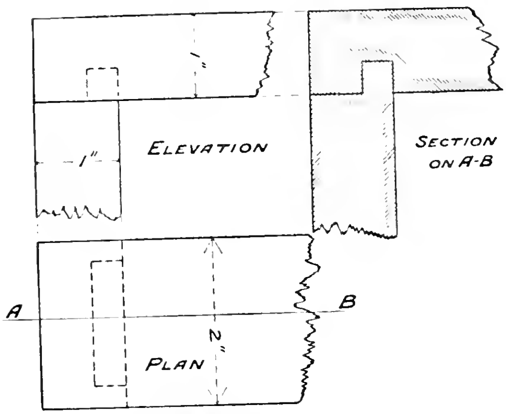


Fig 29

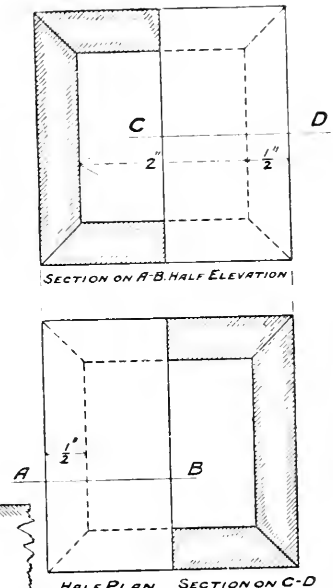


Fig 30

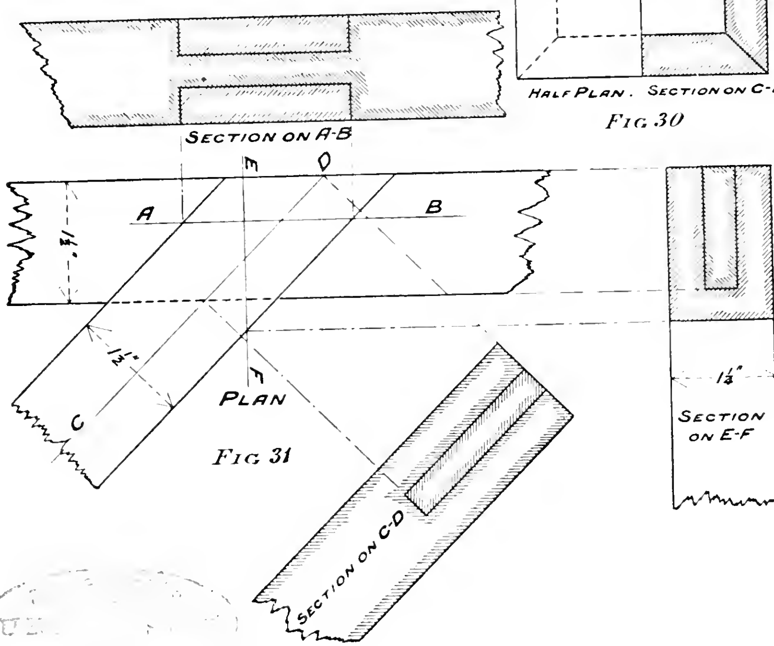


Fig 31

PLATE 8

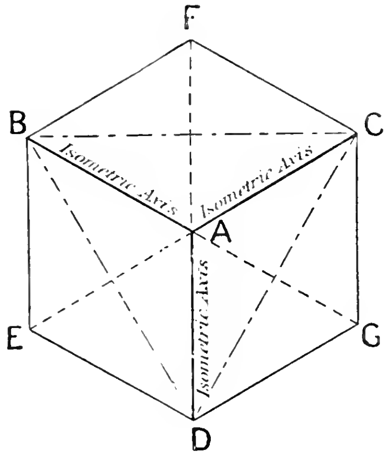


Fig. 32

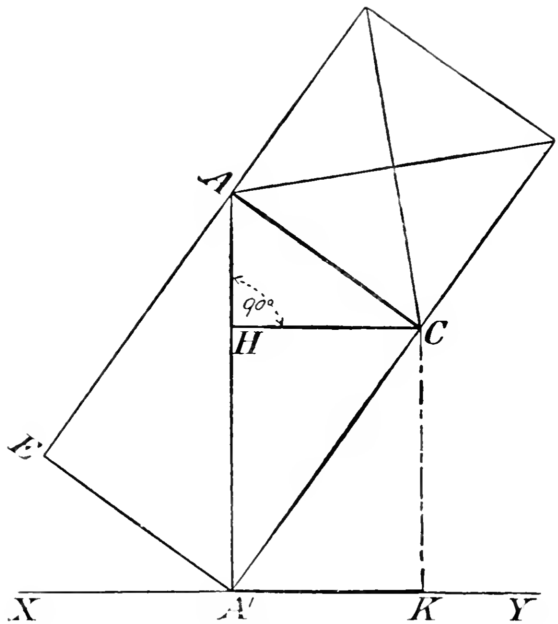


Fig. 33

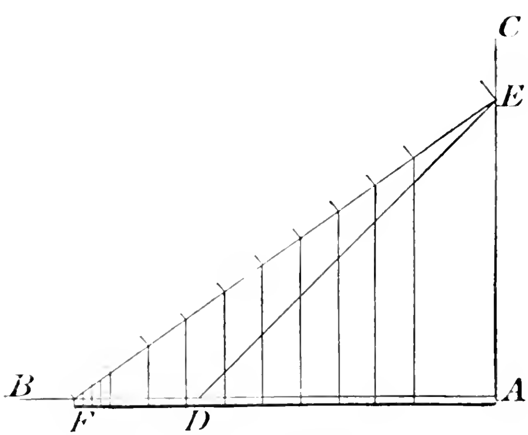


Fig. 34

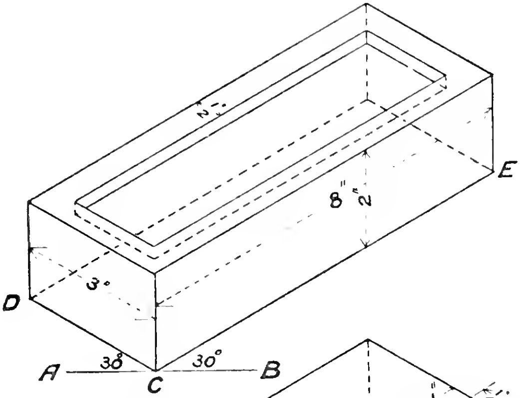


FIG 35

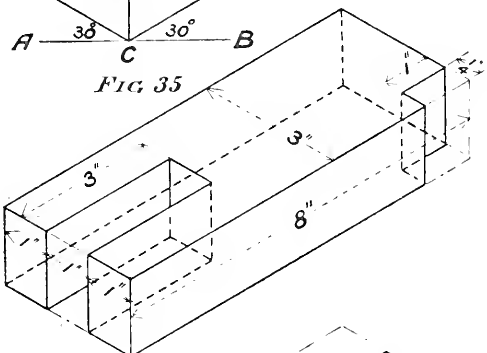


FIG 36

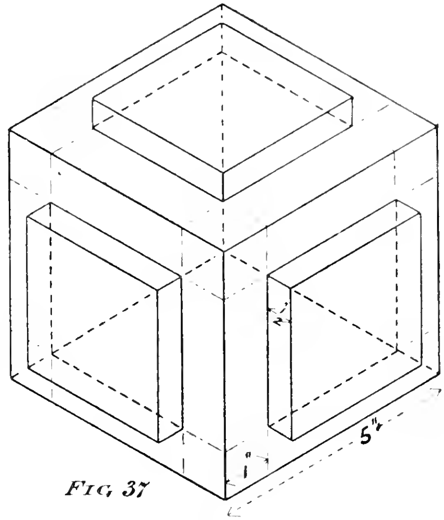


FIG 37

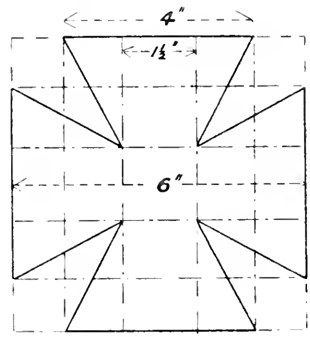


FIG 40

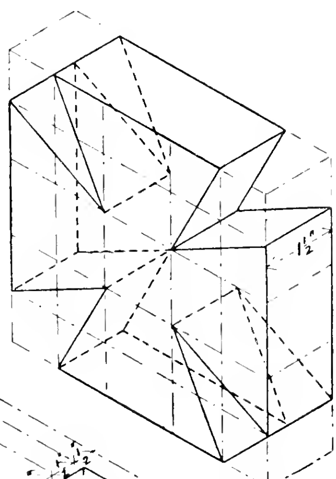


FIG 41

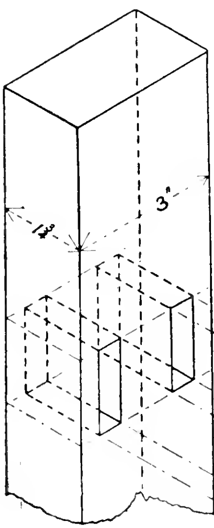
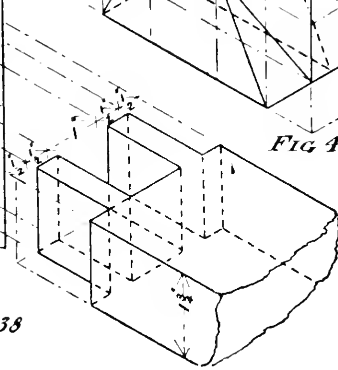



FIG 38

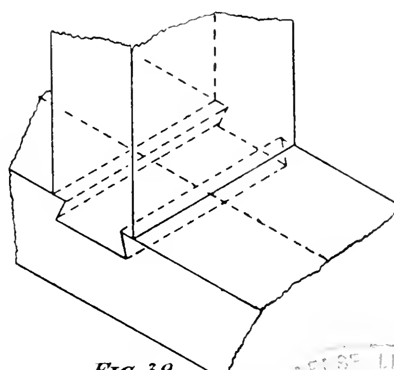
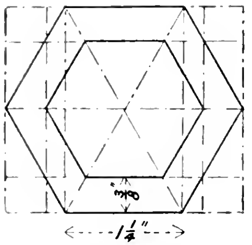
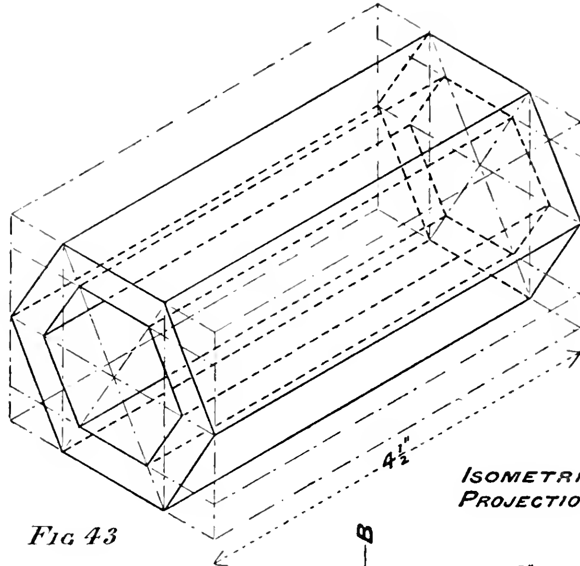


FIG 39

PLATE 10

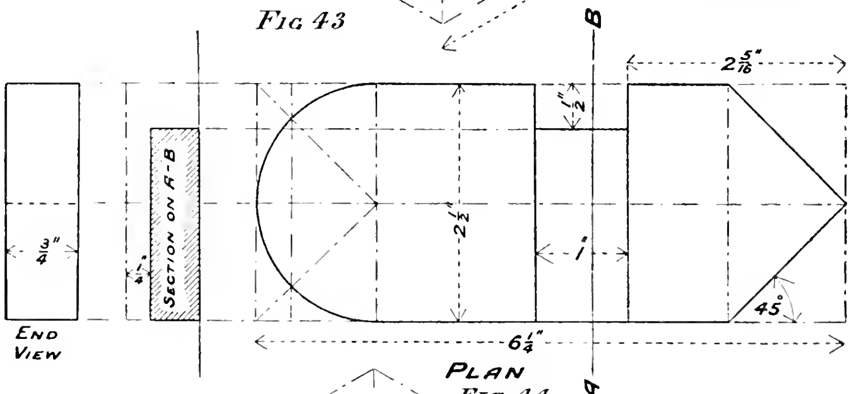


End Elevation
Fig 42

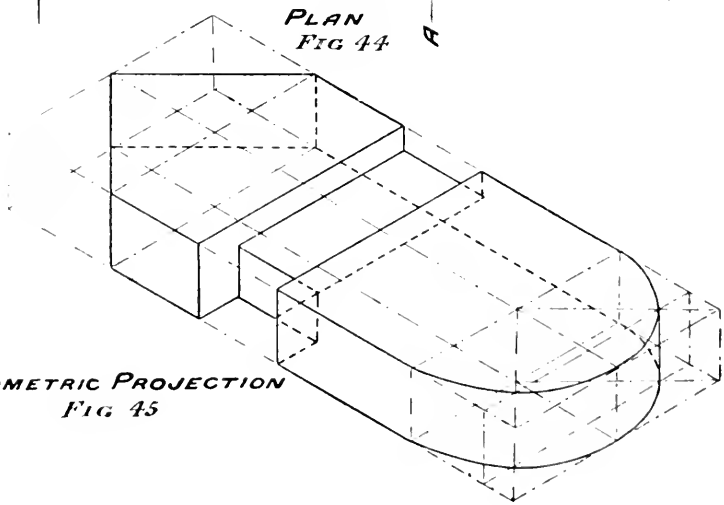


Isometric Projection

Fig 43



Plan
Fig 44



Isometric Projection
Fig 45

PLATE 11

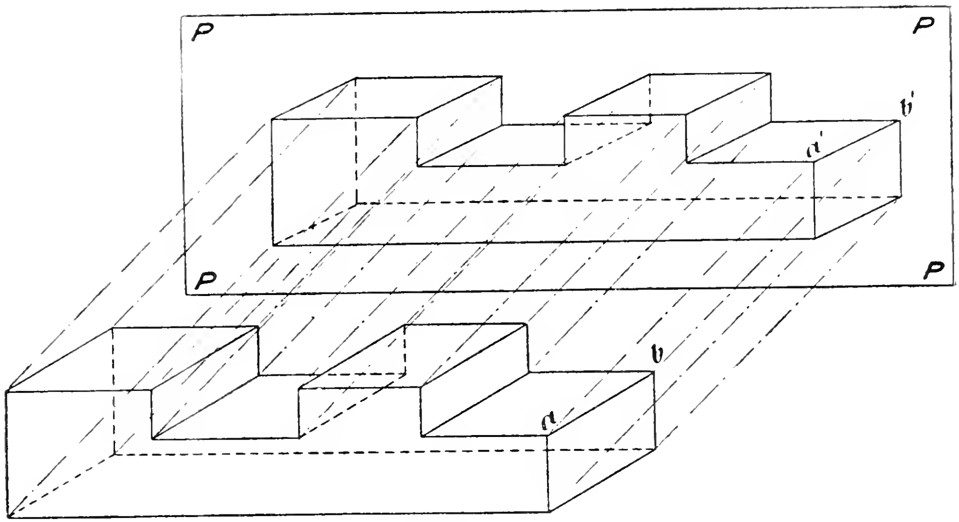


Fig 46

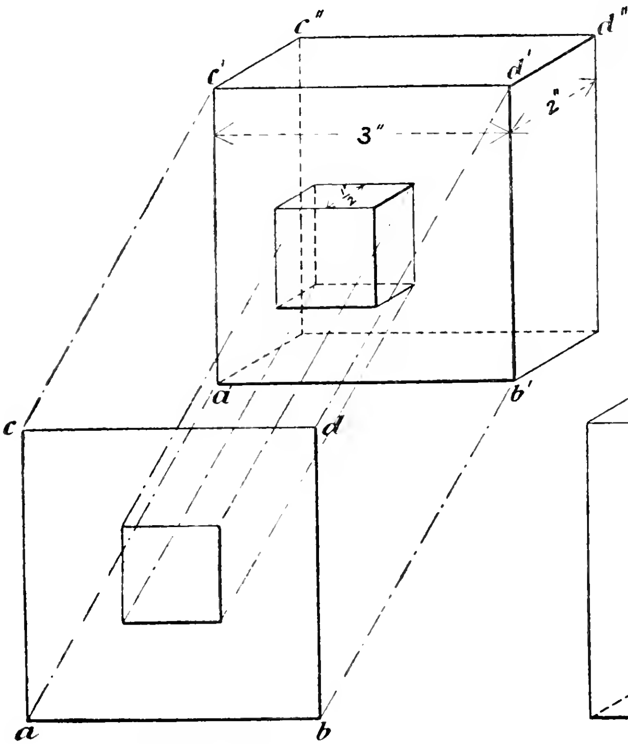


Fig 47

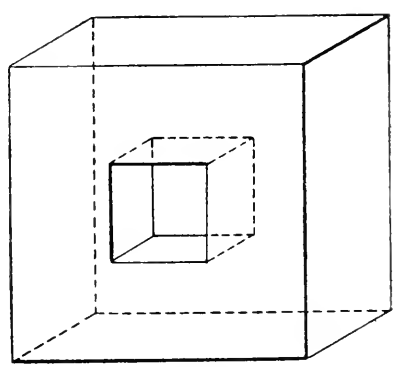


Fig 48

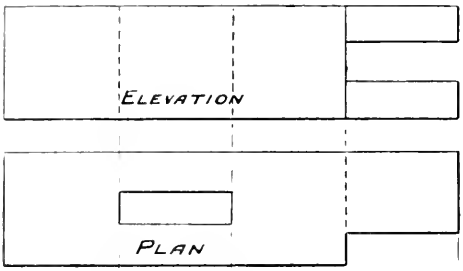


FIG 49

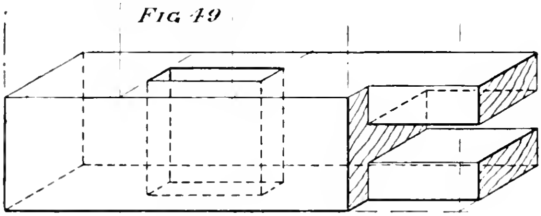


FIG 50

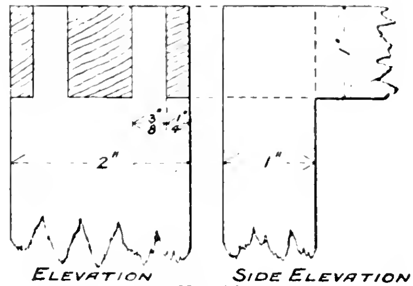


FIG 51

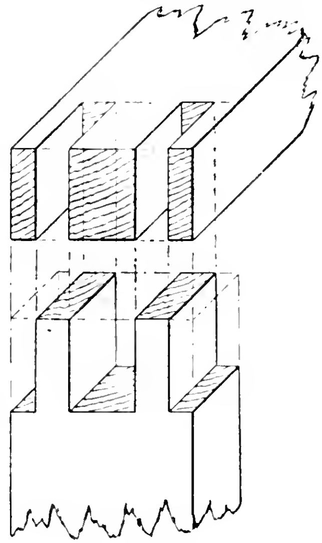


FIG 52

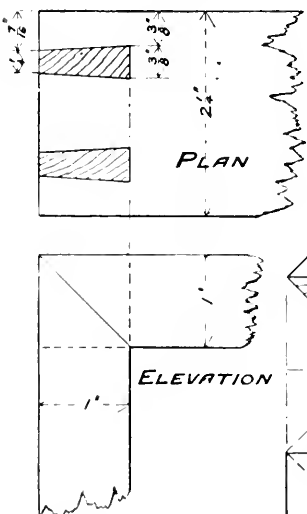


FIG 53

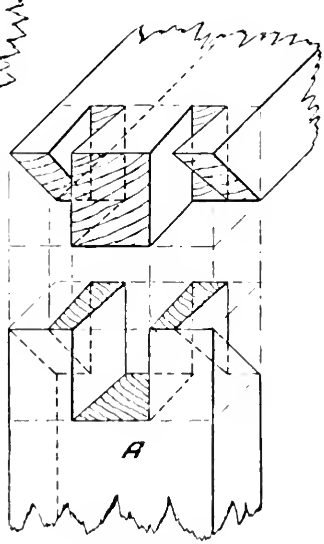


FIG 54

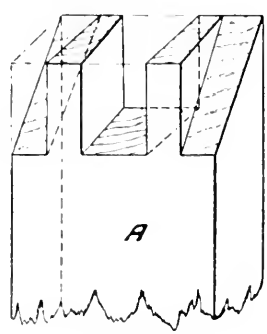


FIG 55

PLATE 13

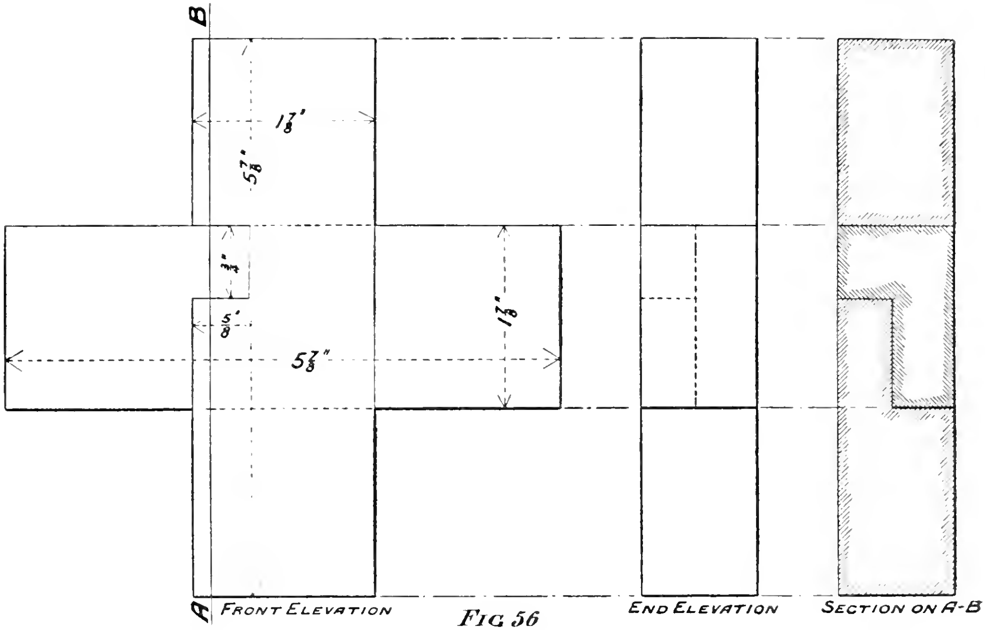


FIG 56

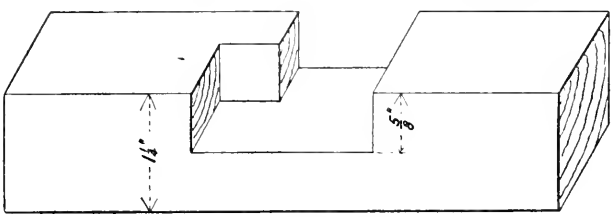
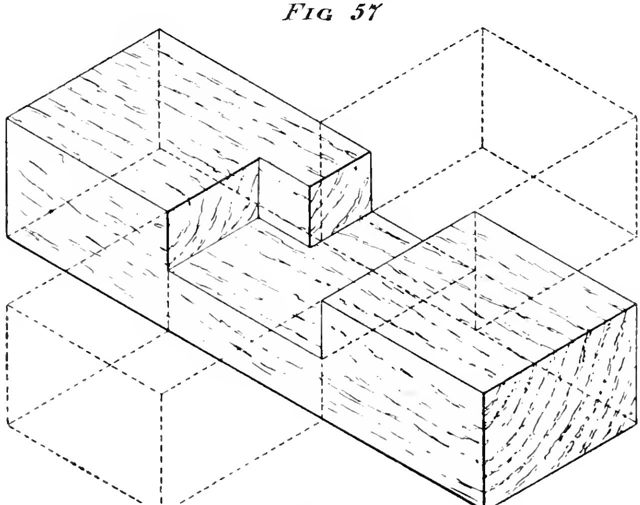


FIG 57



ISOMETRIC PROJECTION

FIG 58

PLATE 14

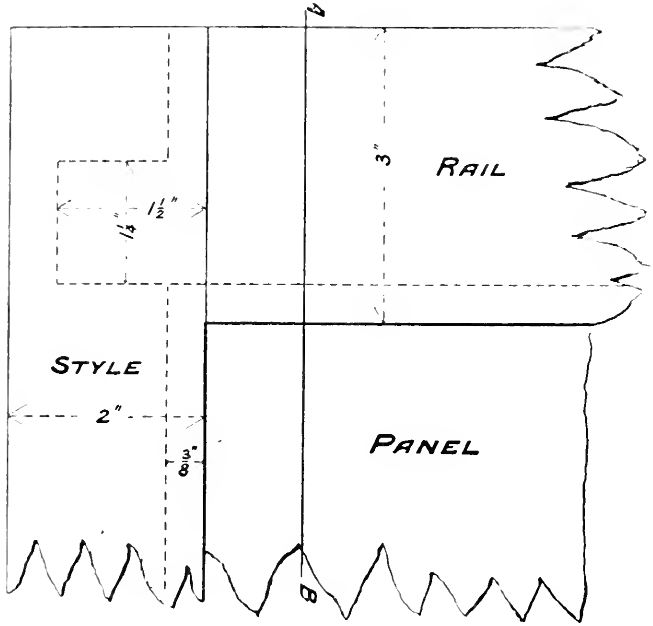


FIG 59

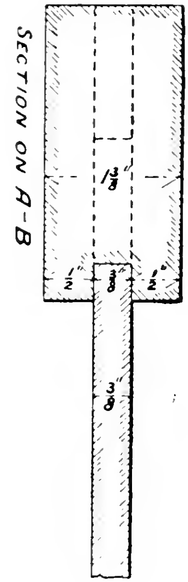


FIG 60

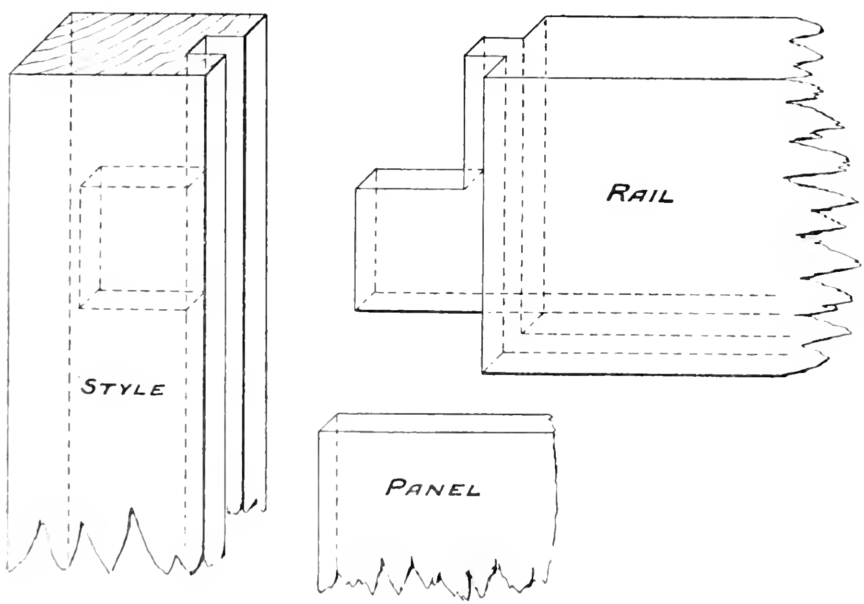


FIG. 61

PLATE 15

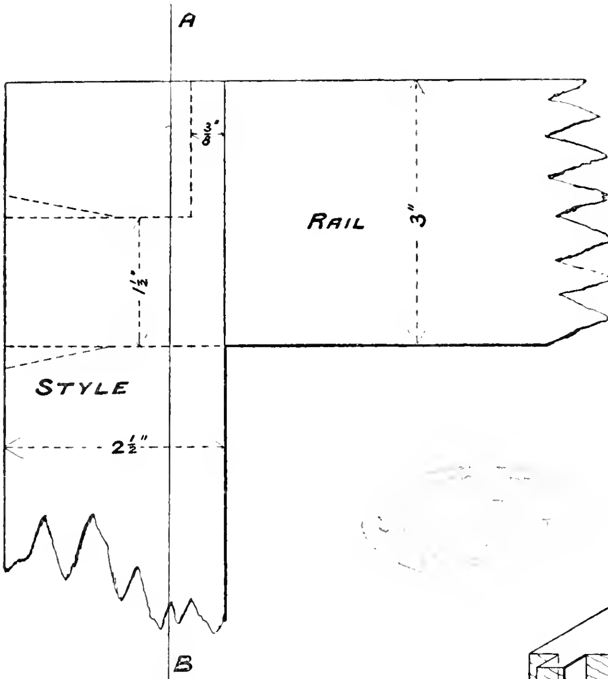


Fig 62

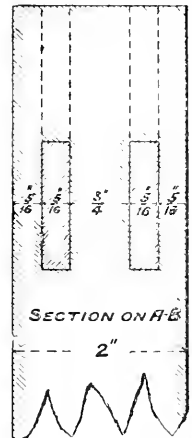
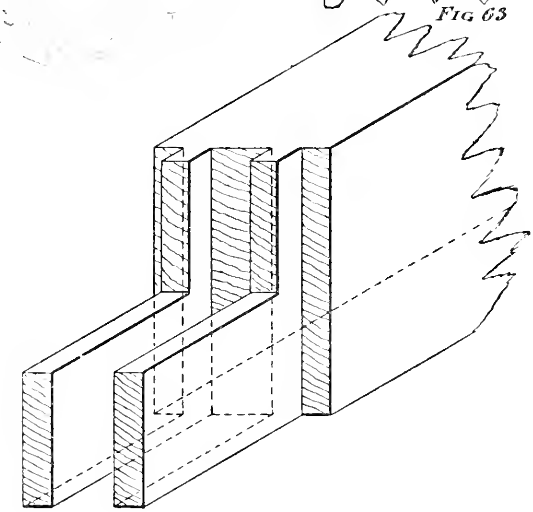


Fig 63



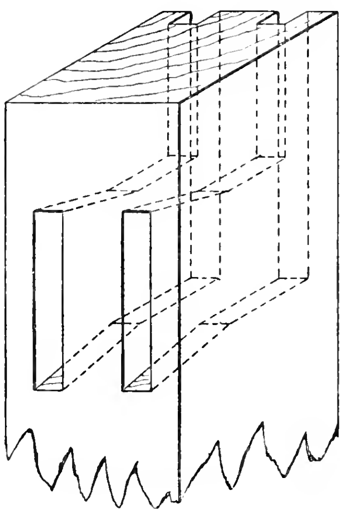


Fig 64

OBLIQUE PROJECTION

PLATE 16

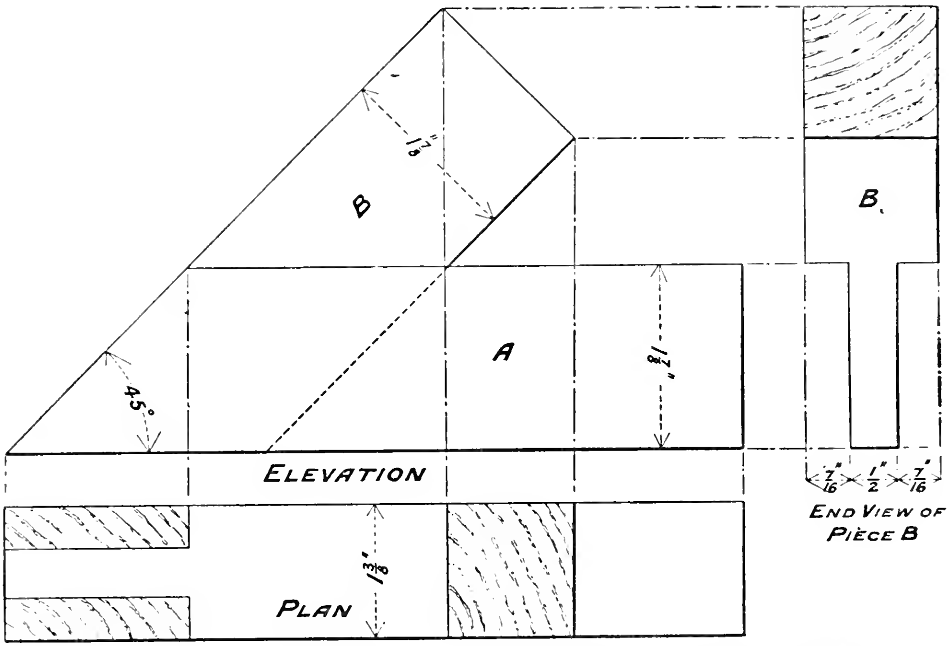


FIG 65

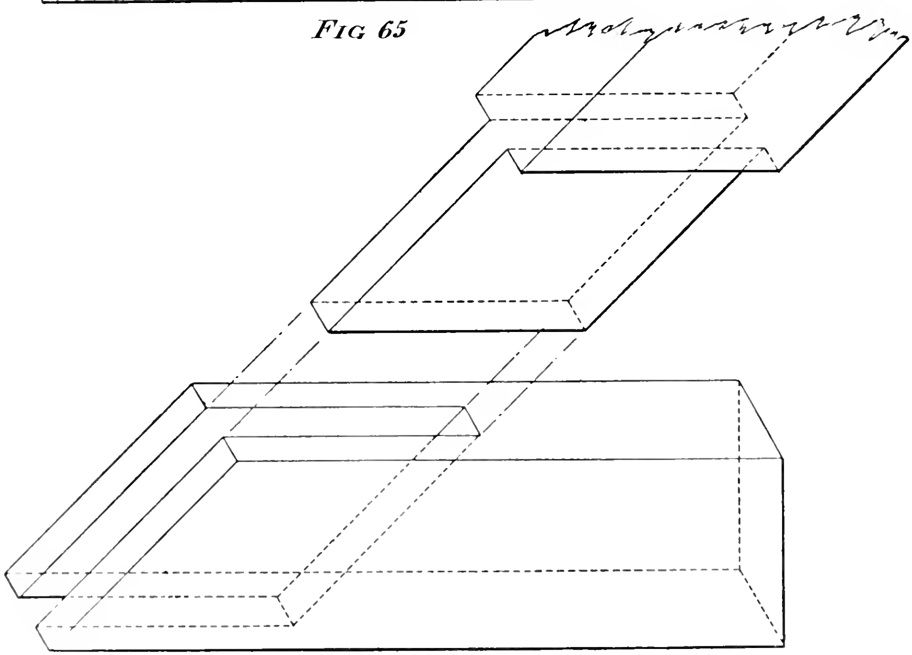
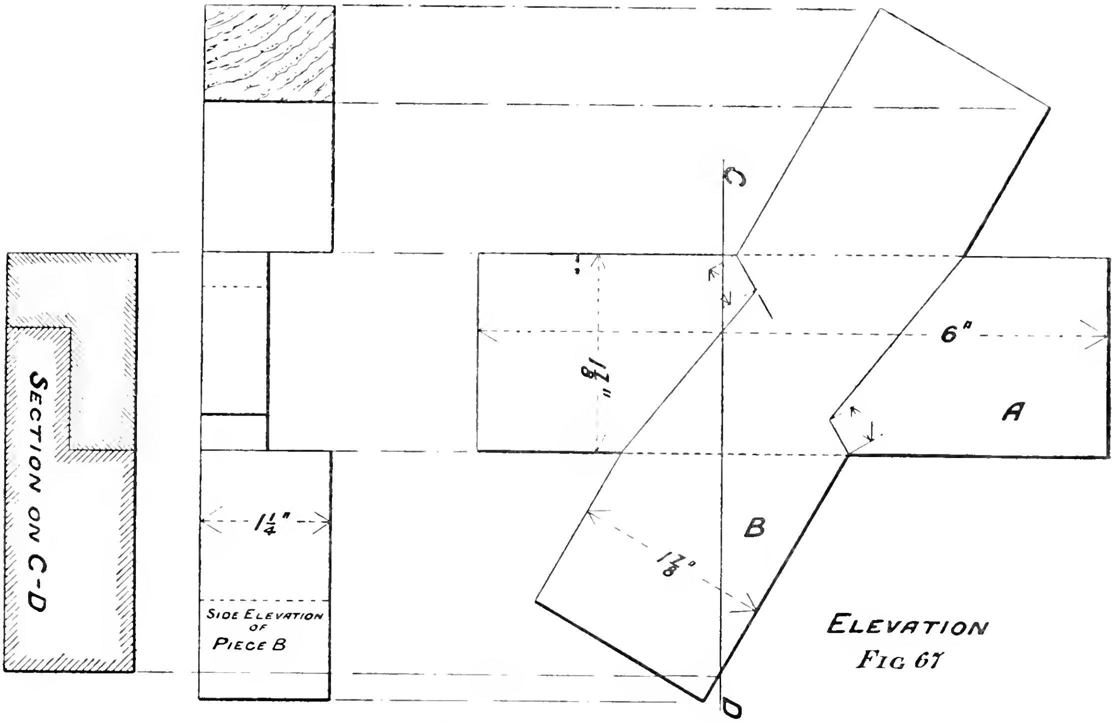


FIG 66

PLATE 17



Elevation
Fig 67

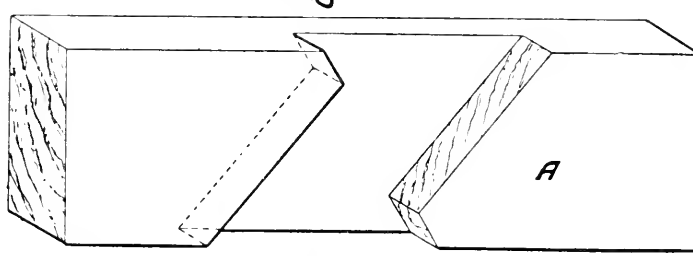
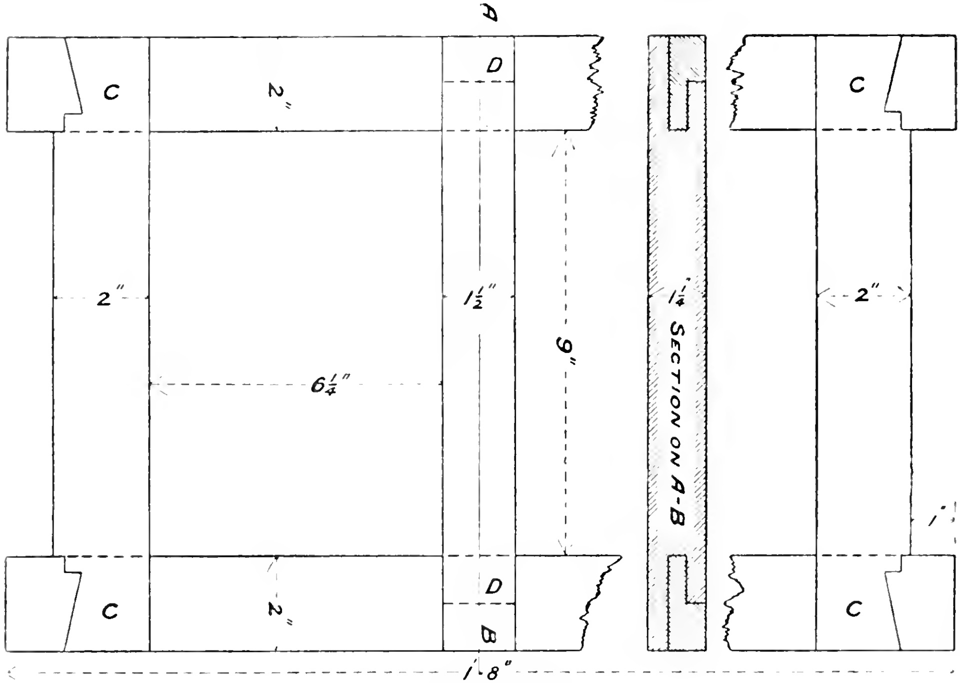


Fig 68

F

PLATE 18



ELEVATION
FIG 69

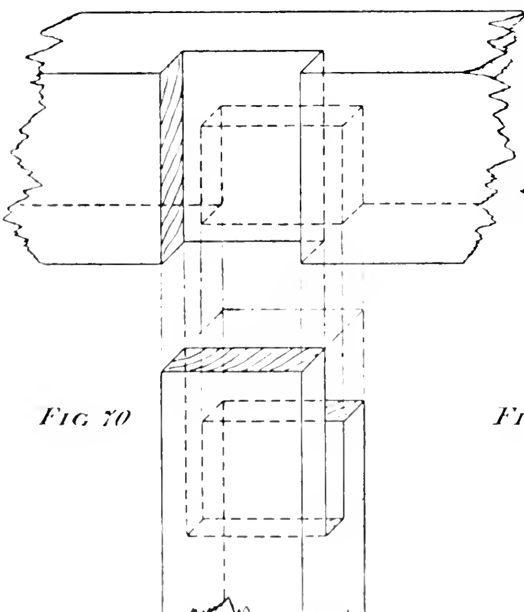


FIG 70

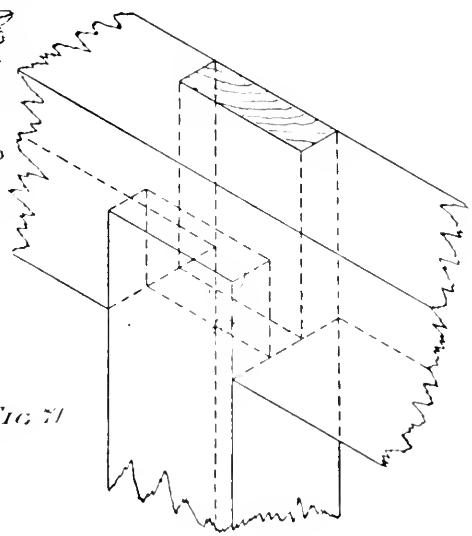


FIG 71

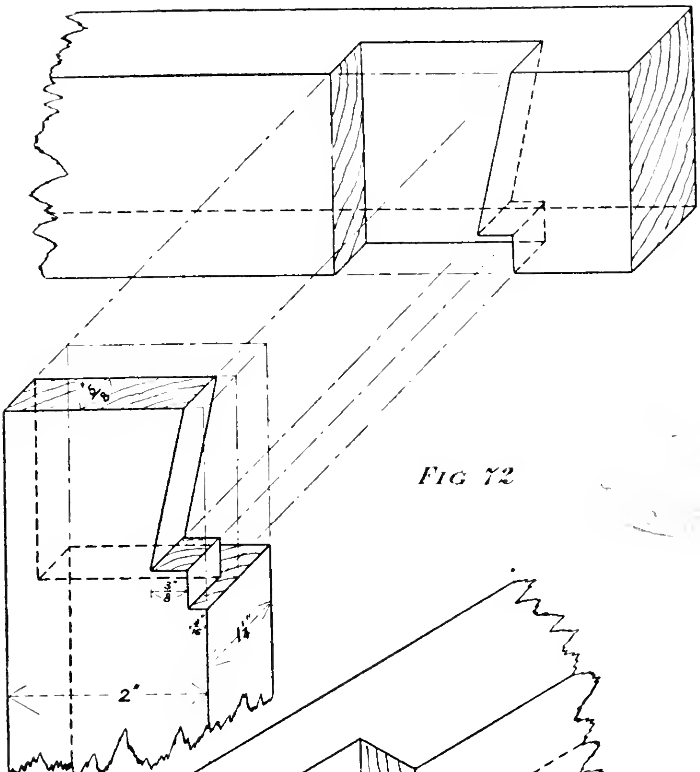


FIG 72

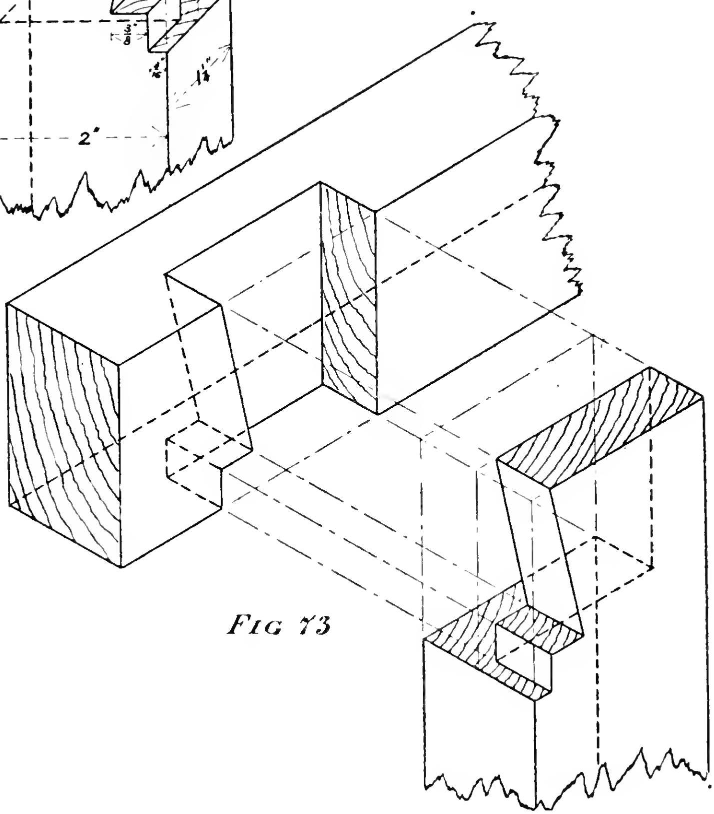


FIG 73

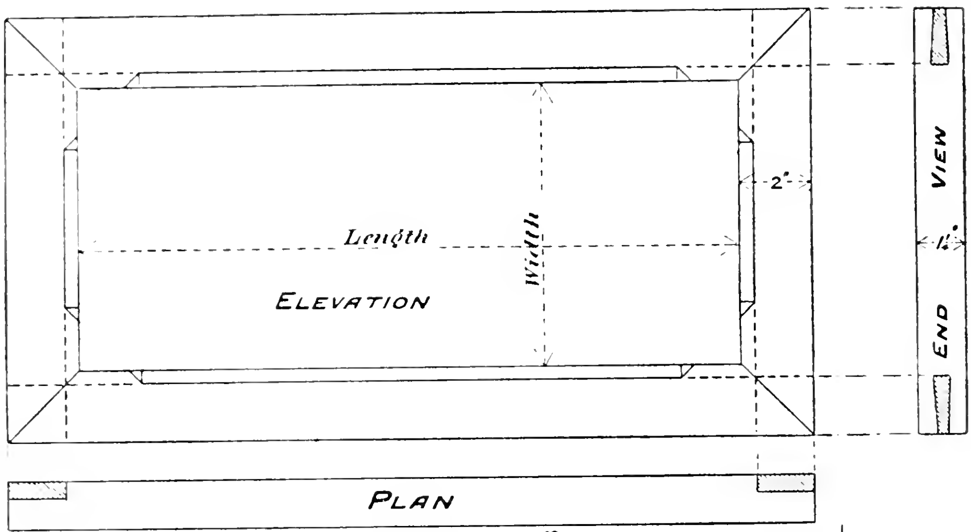


FIG 74

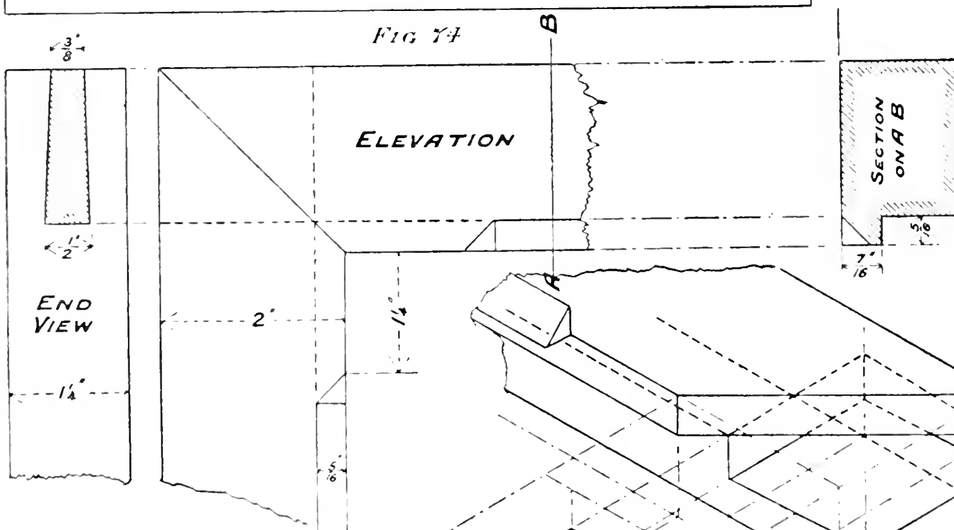


FIG 75

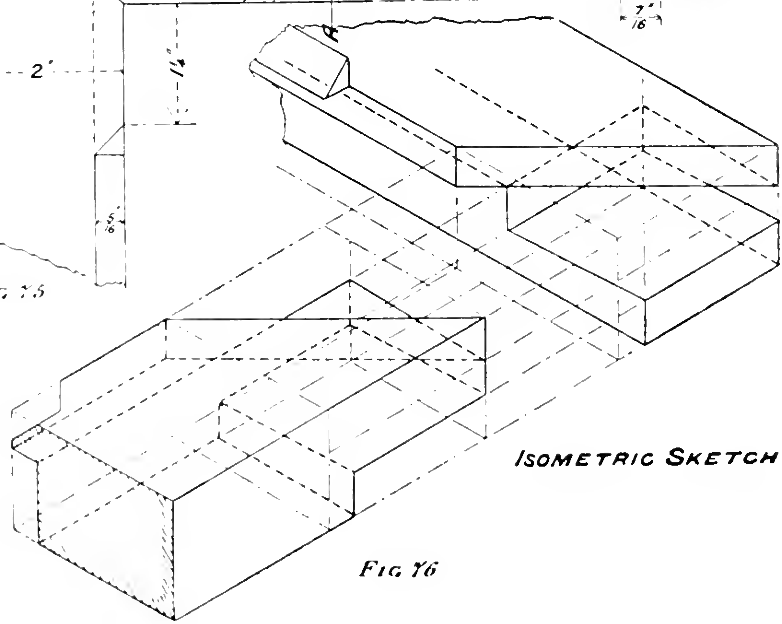


FIG 76

PLATE 21

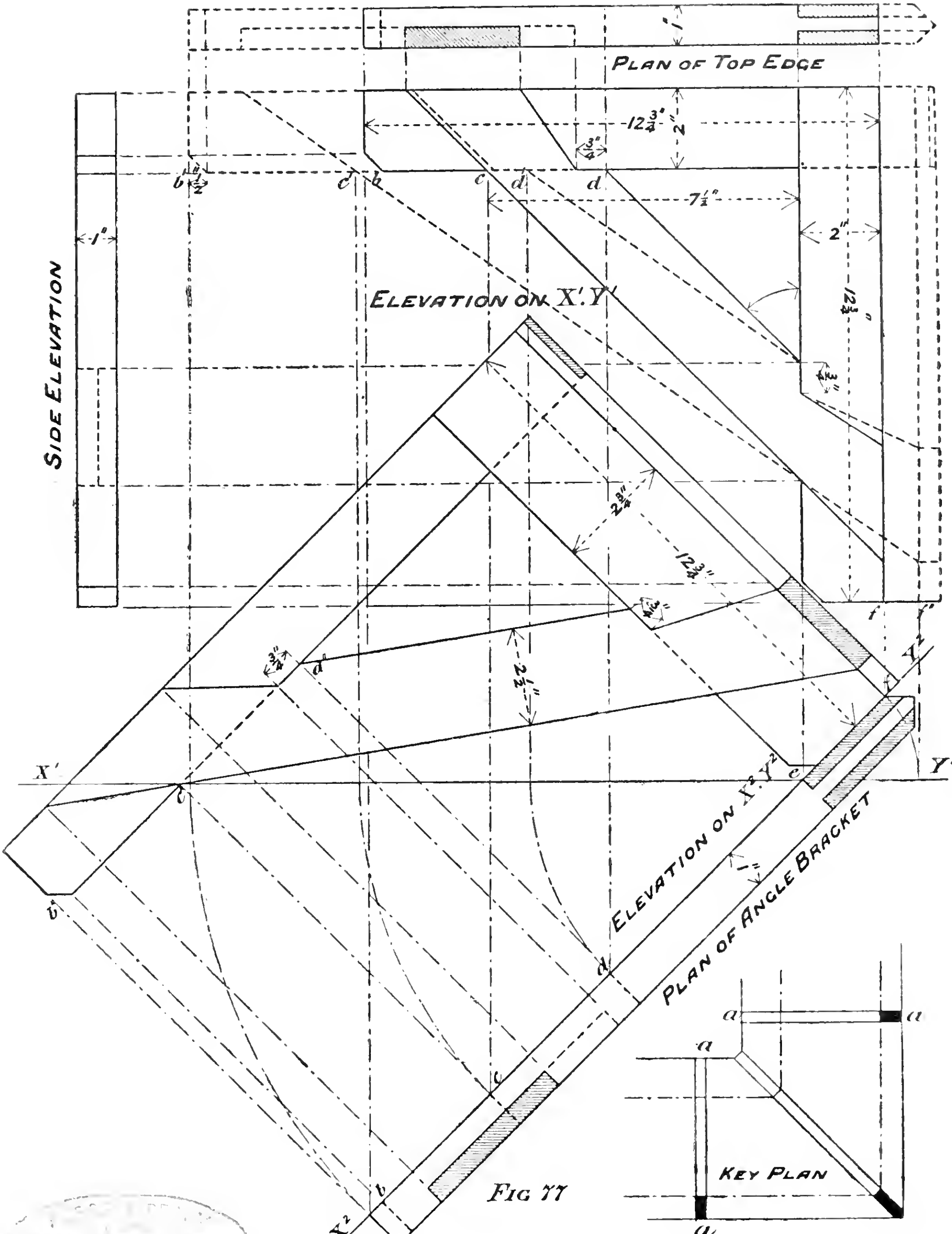


FIG 77

PLATE 22

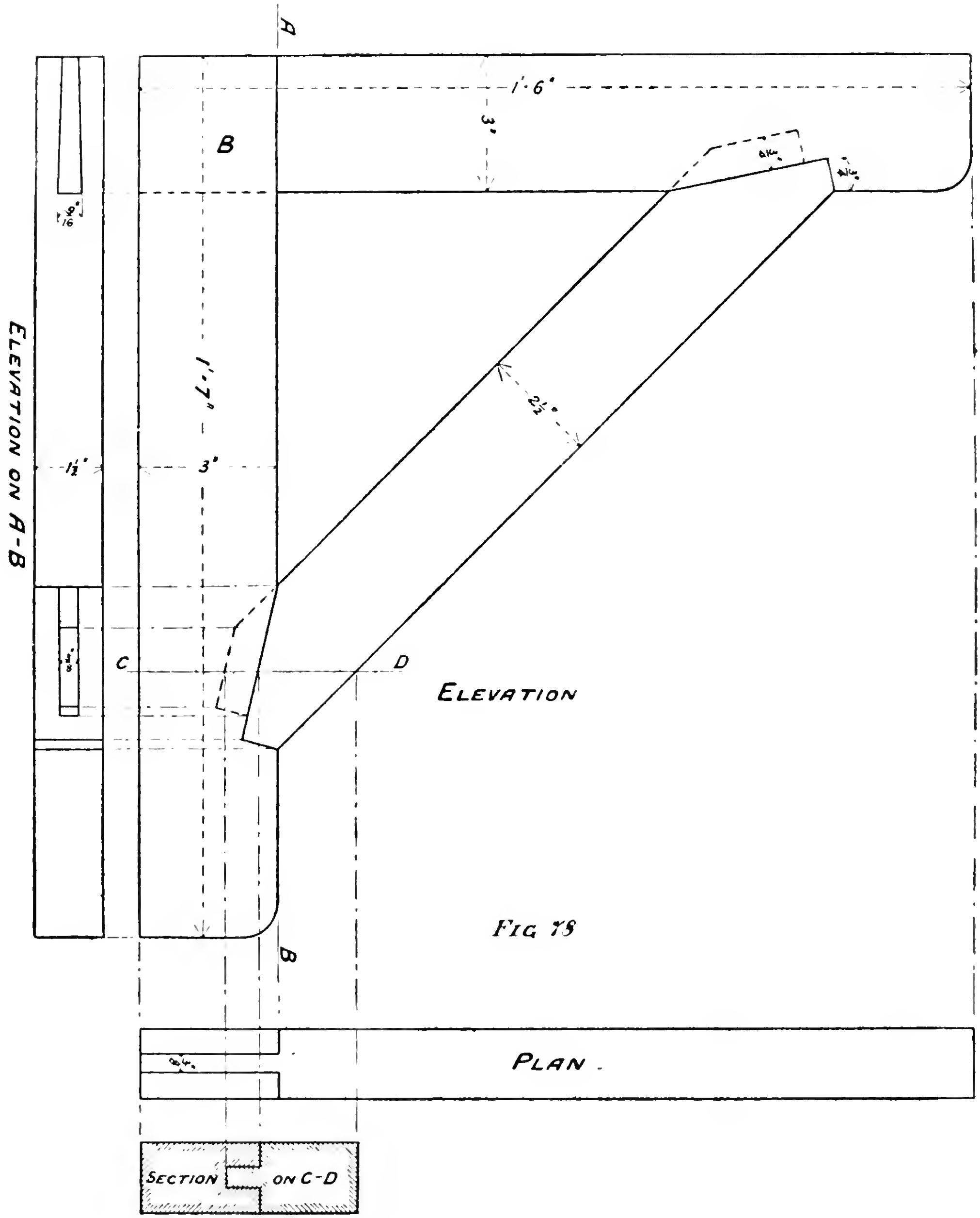
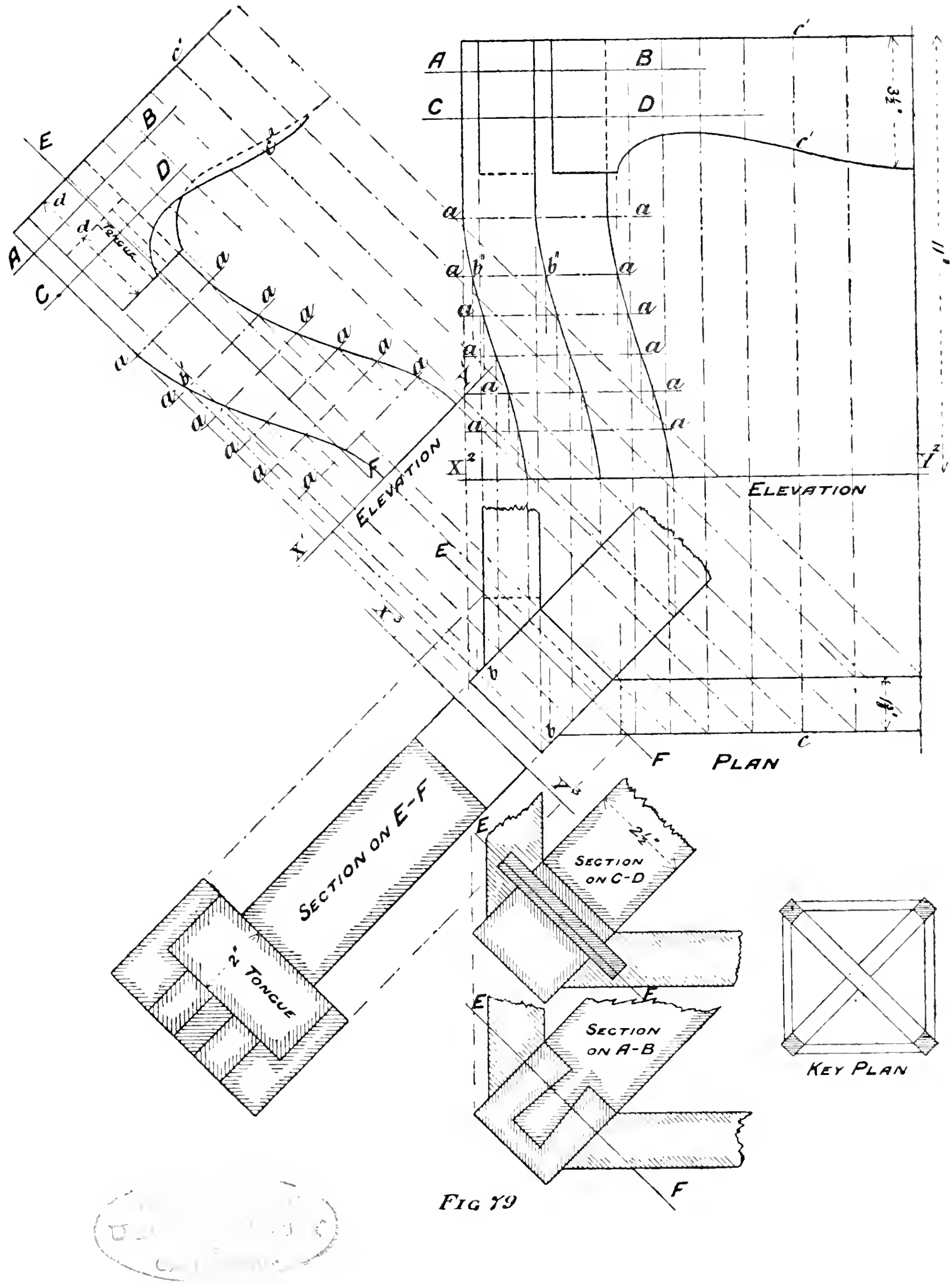


FIG 78



ELEVATION
ELEVATION
PLAN
SECTION ON E-F
SECTION ON C-D
SECTION ON A-B
2" TONGUE
TONGUE
KEY PLAN
3¼"
11"
2¼"

FIG 79

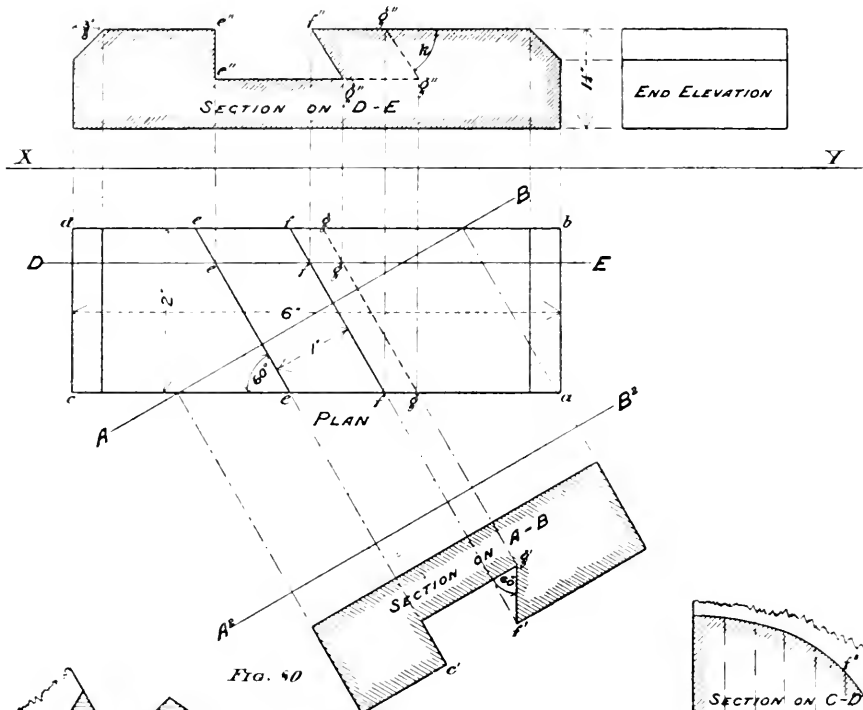


FIG. 80

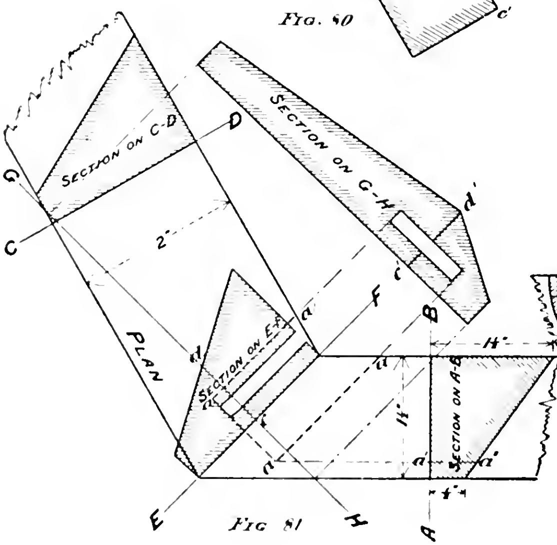


FIG 81

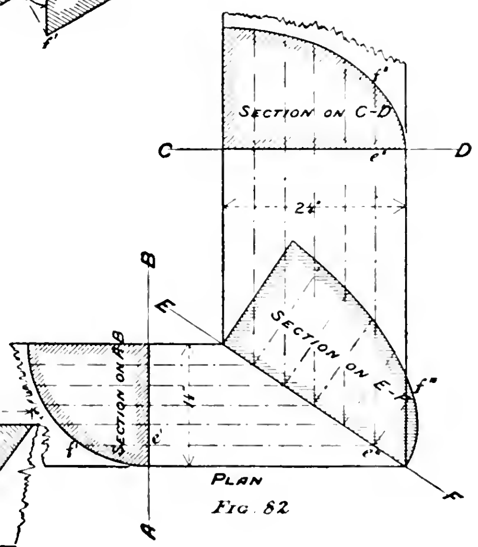


FIG. 82

PLATE 25

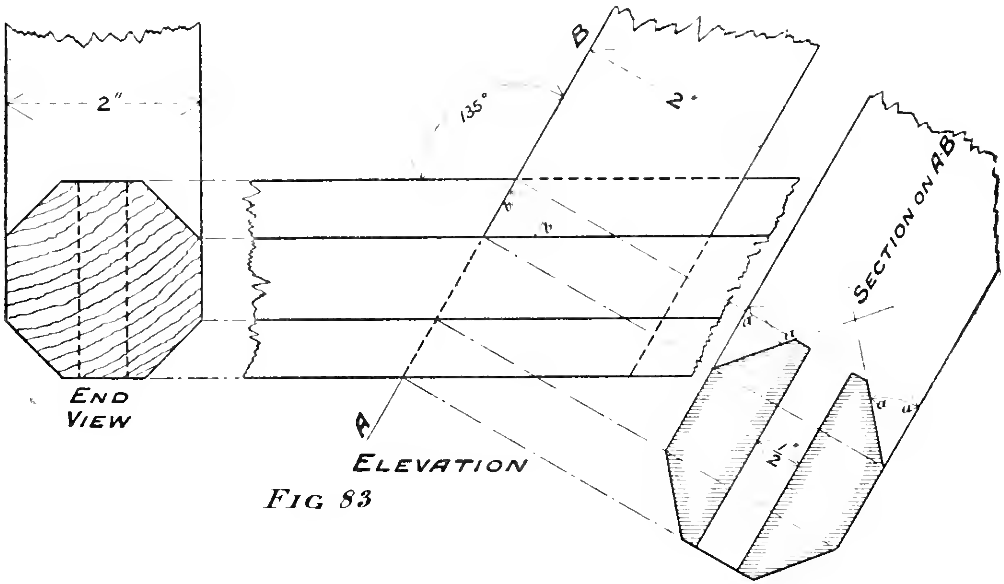


FIG 83

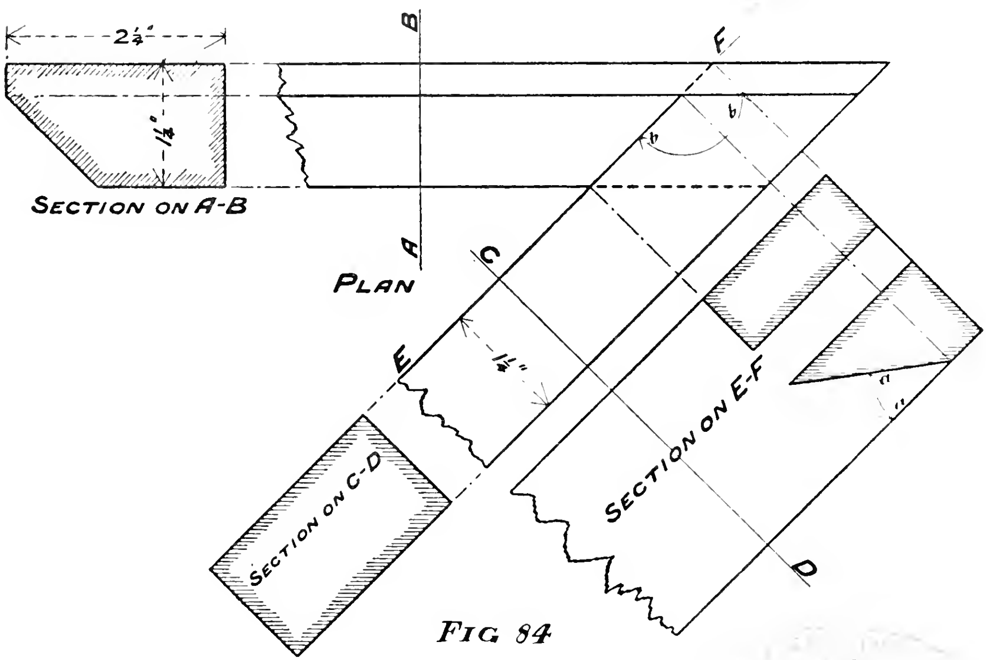


FIG 84

PLATE 26

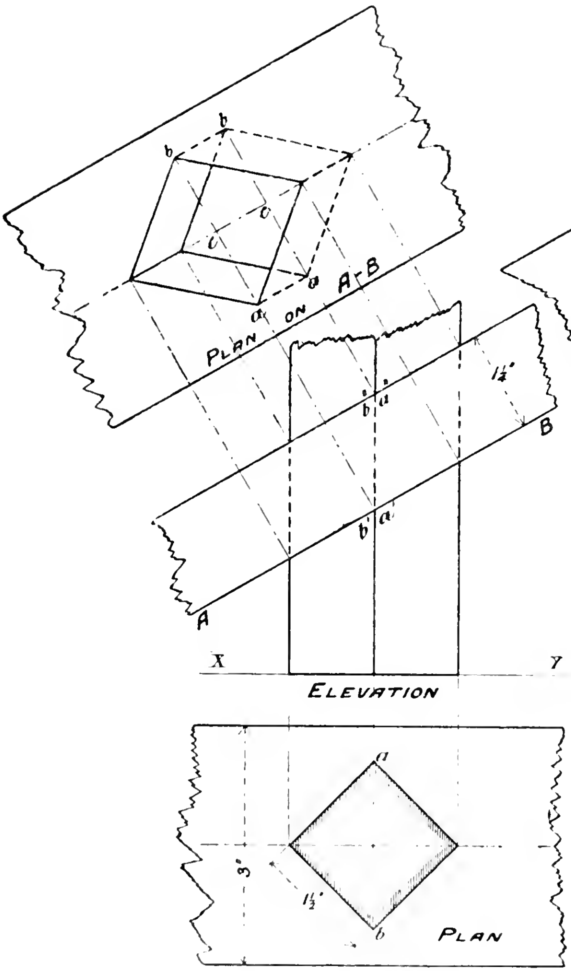


FIG 85

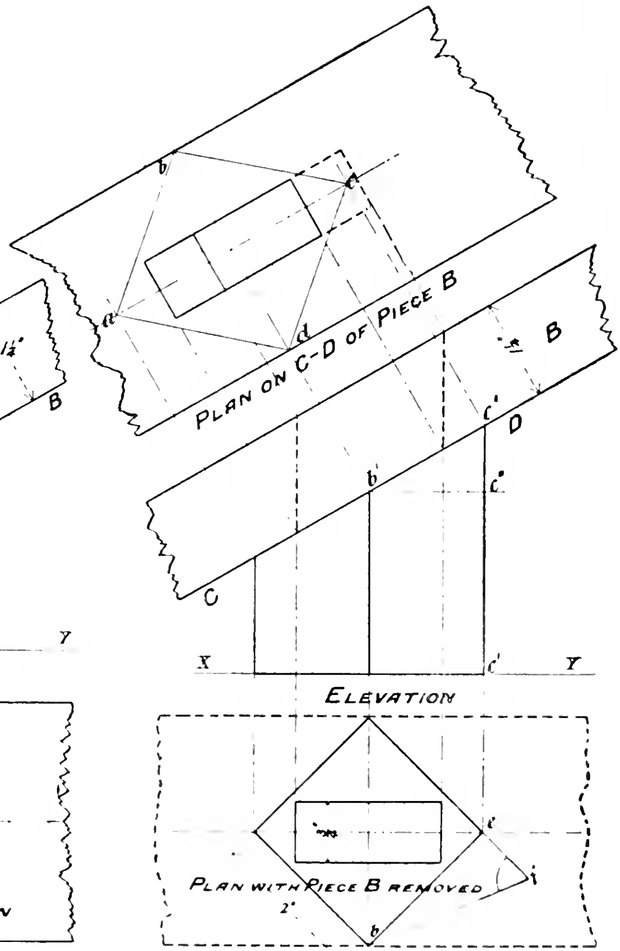


FIG 86

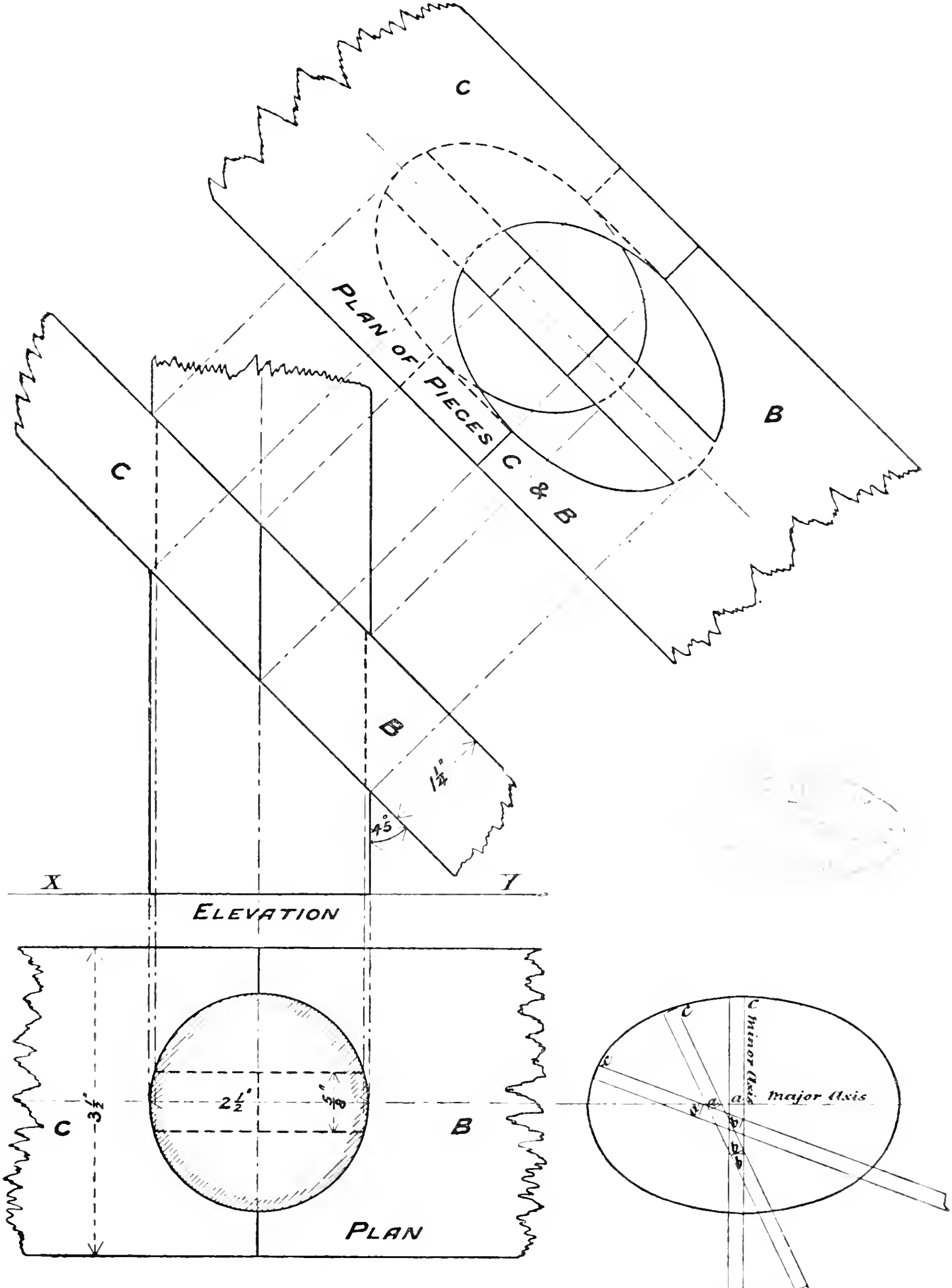

C
PLAN OF PIECES C & B
B
C
B
1¼"
45°
X
Y
ELEVATION
C
3½"
2½"
⅝"
B
PLAN
c
c
c
minor Axis
major Axis
a
a
a
b
b

FIG. 88

PLATE 28

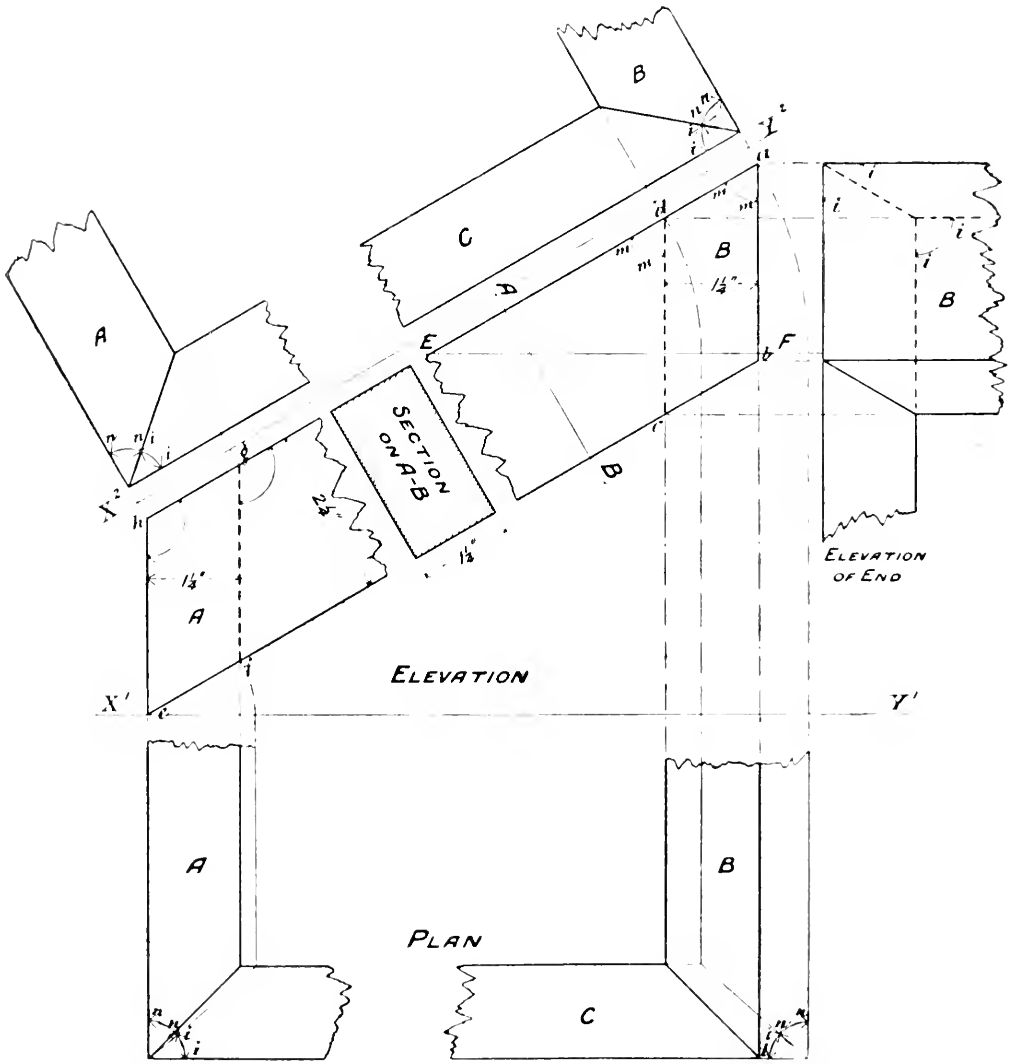


FIG. 89

PLATE 29

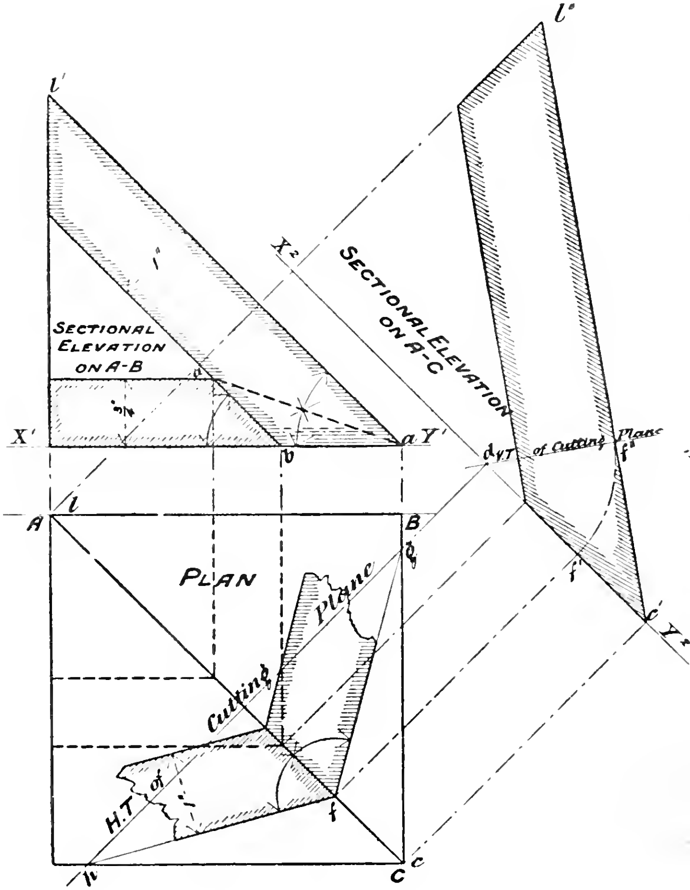


FIG 91

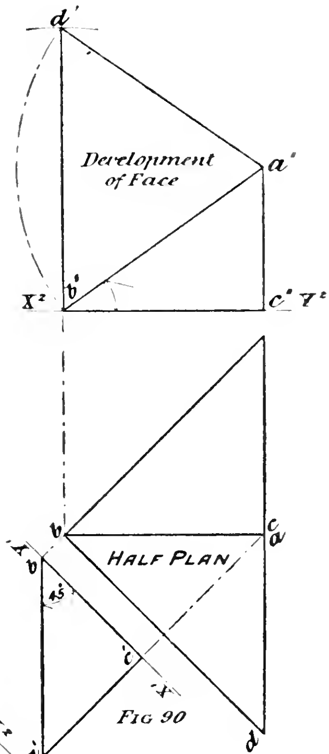


FIG 90

PLATE 30

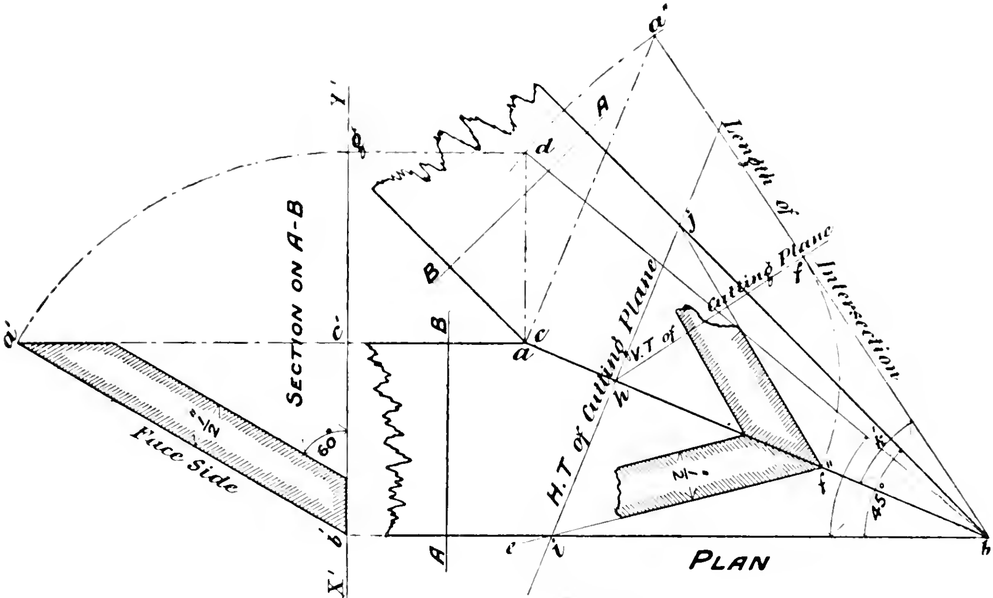


FIG 92

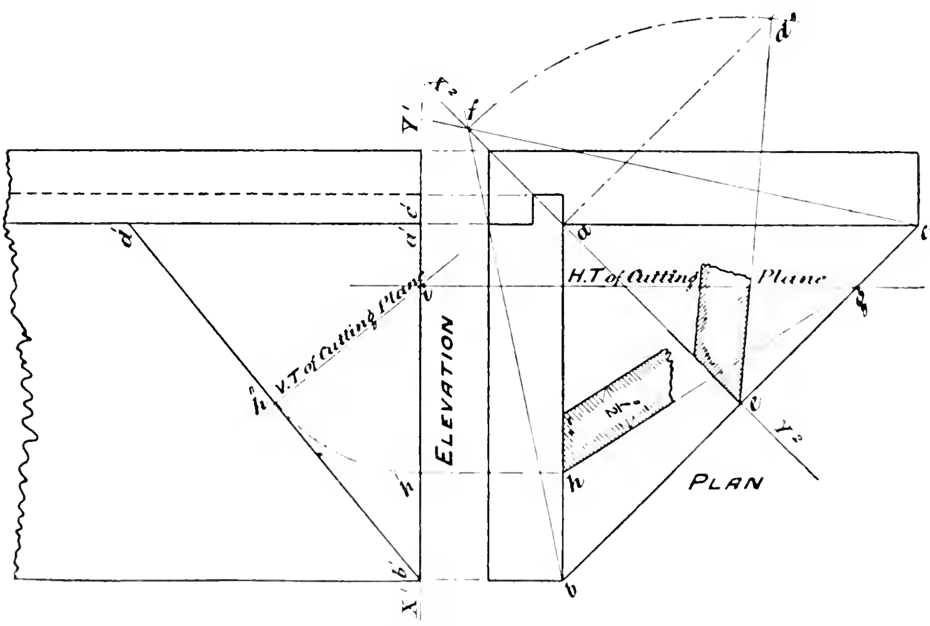
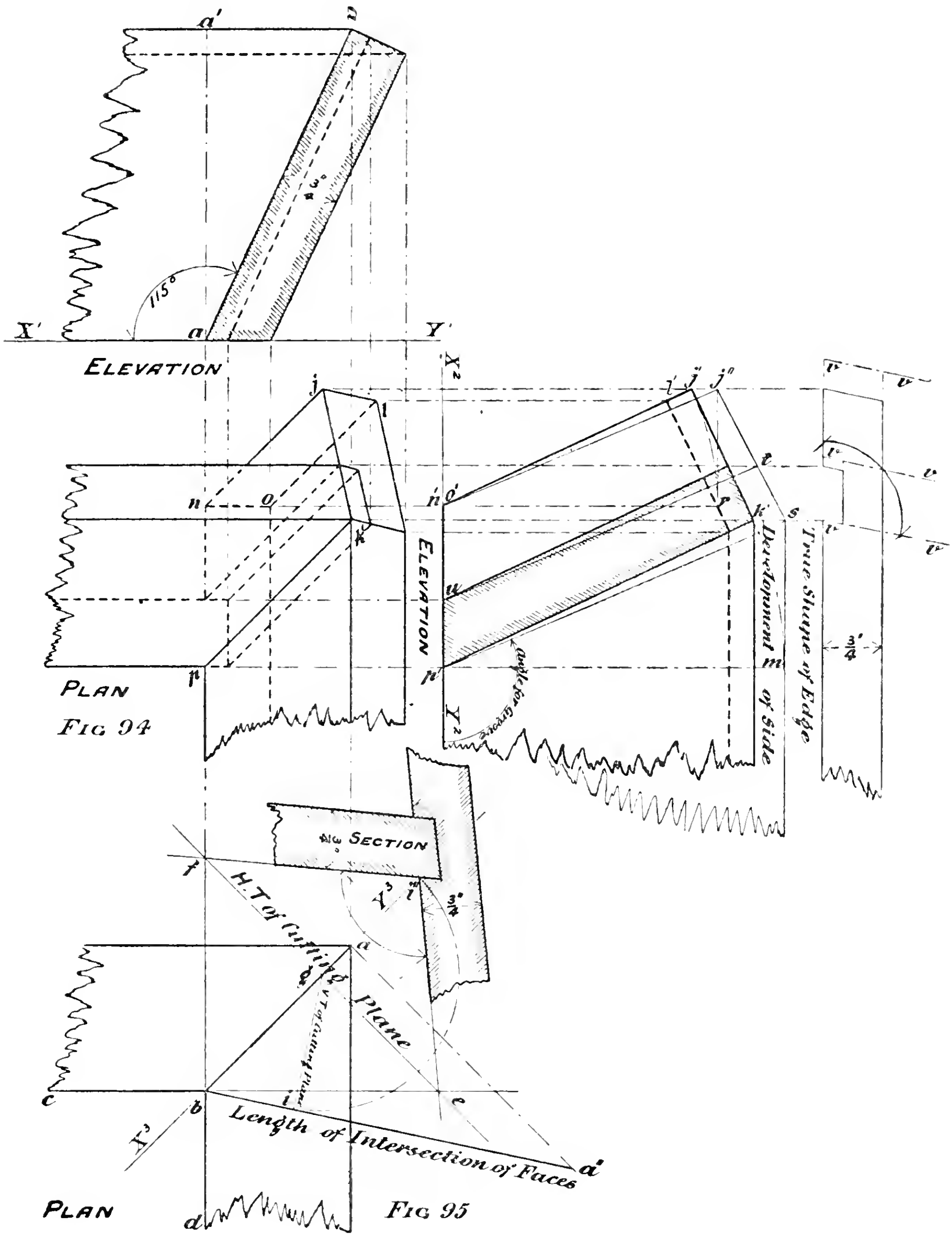


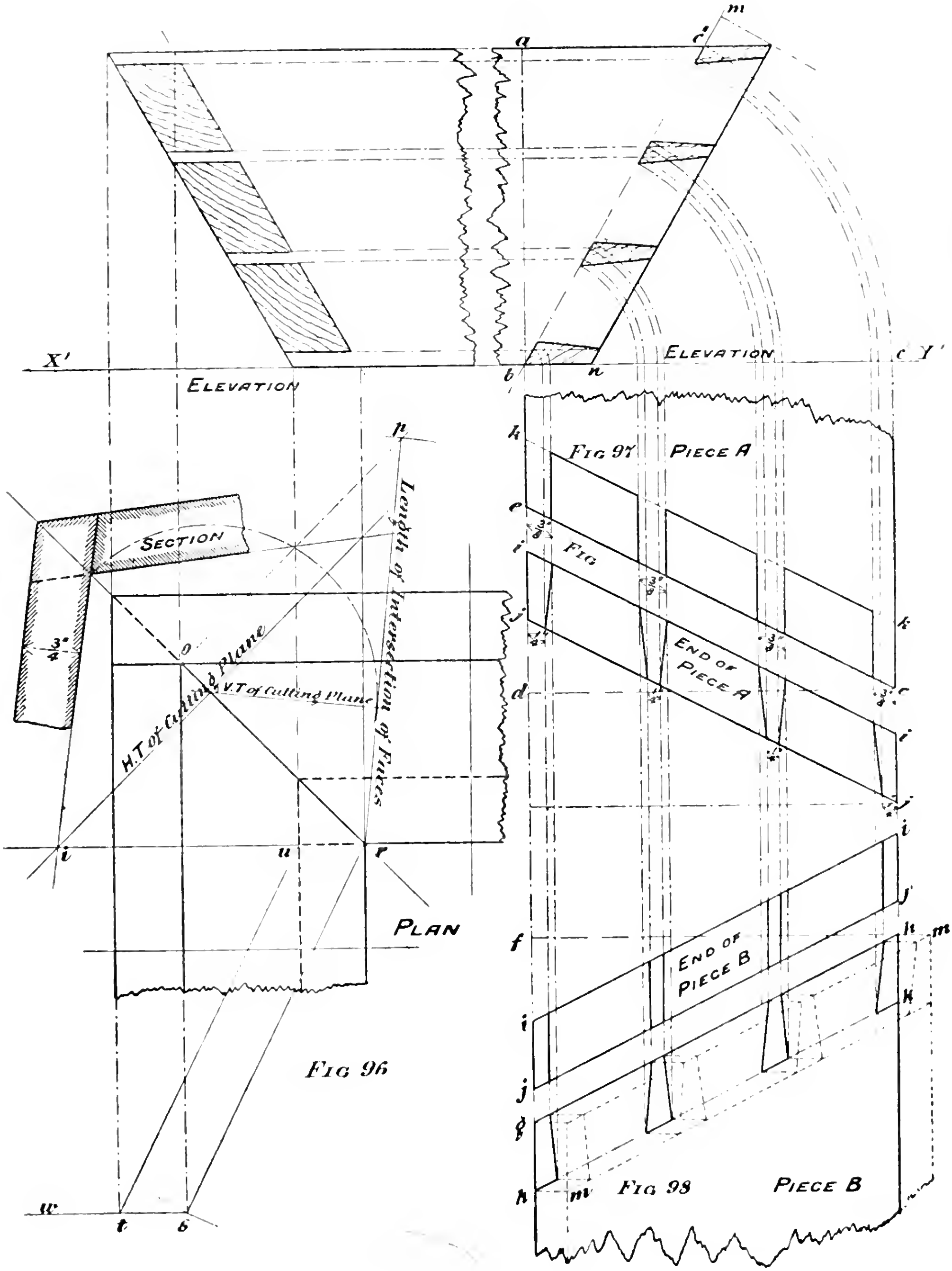
FIG 93

PLATE 31



Elevation
Plan
Fig 94
Elevation
Development of Side
True shape of Edge
Angle for Groove
Section
H.T. of Cutting Plane
V.T. of Cutting Plane
Length of Intersection of Faces
Plan
Fig 95

PLATE 32



ELEVATION
ELEVATION
SECTION
H.T of Cutting Plane
V.T of Cutting Plane
Length of Intersection of Faces
PLAN
FIG 96
FIG 97
PIECE A
END OF PIECE A
END OF PIECE B
FIG 98
PIECE B

G

MODEL
5. Planing in the direction of the grain to a prismatic form.
6. An elliptical mat.
7. A letter rack, face and edge planing, boring and screwing.
7a. Another form of letter rack.
7b. Another form of hanging rack.
8. A lamp or vase stand.
9. A bracket.
10. An Oxford picture frame.
11. A towel roller.
12. A newspaper rack.
13. Another form of hanging newspaper rack as an alternative to the preceding.
14. School pen tray.
15. Application of the mortice and tenon joint in making a mirror frame—rebating.
16. Triangular framing carrying shelves.

MODEL
17. An inlaid handled tray.
18. Picture frame involving mitred angle bridle joint.
19. Standing picture frame.
20. Inkwell with swinging lid.
21. Bracket (hanging) with chamfered edges.
22. Hat pegs (set of).
23. Inkstand.
24. Pen rest.
25. Footstool, involving the haunched tenon joint.
26. Framed bracket shelf.
27. Box with common dovetailed joints.
28. Box (hanging).
29. Inlaid parquetry tray with common dovetailed joint.
30. Book rack made with the lapped dovetailed joint.

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unfold it. The two planes with their 'trace' will then be given.

The arcs show the direction of the folding of the vertical plane into the horizontal plane, and the intersection, or trace, is the ground line, X Y. The four dihedral angles of the co-ordinate planes are numbered 1 to 4.

No. 1 is in front of the vertical plane, and over the horizontal

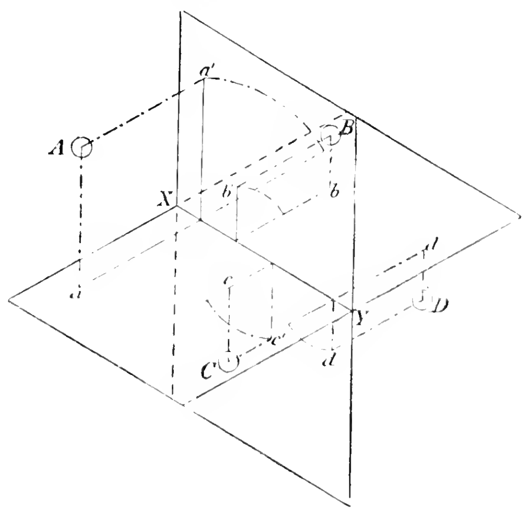

Fig. 6.

plane; No. 2 is behind the vertical plane, and over the horizontal plane.

No. 3 is below the horizontal plane, and behind the vertical plane, and No. 4 is in front of the vertical plane, but under the horizontal plane.

Suppose a point A exists 1 in. above the horizontal plane, and 1 in. in front of the vertical plane, then the plan will be 1 in. in front of the trace, or X Y, and the elevation 1 in. above. Fig. 6

SPECIMEN PAGE.

that logs are not split in this way because the shape is preferred to that of a log, but to save worse splitting taking place. In fact, the inevitable splitting is recognised, and the halving and quartering being the forms in which least waste in conversion would probably arise, they are cut up in this way as being the least wasteful plan.

Owing to the frequent lopping of small branches and shoots, the bending and twisting of growing trees due to prevailing winds and other causes, the fibres frequently become very twisted and even involved in an extraordinary manner, notably in the large burrs of pollard oaks and willows.

These latter wavy twisting fibres are in some woods much valued for ornamental purposes, and trees are sometimes kept well pruned with the intention of producing this peculiarity.

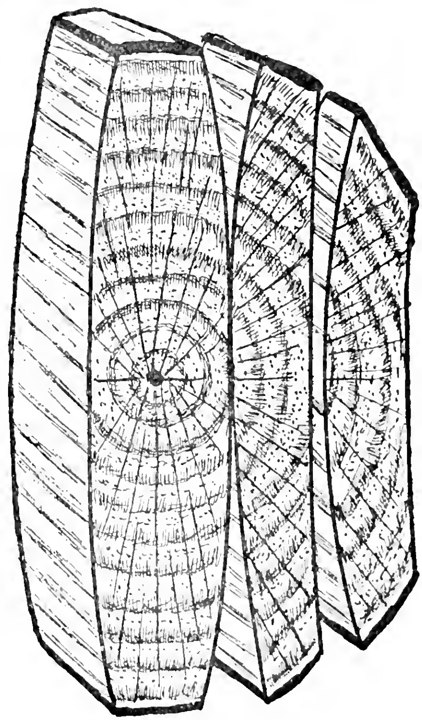

Fig. 26.

Let us consider now the effect of twisted longitudinal fibres in a plank.

Fig. 26 shows the end section of a series of planks cut out

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